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HumRRO

Technical Report 83 April 1963

THE PREDICTION OF TRAINING REQUIREMENTS FOR FUTURE WEAPON SYSTEMS

A Personnel Support System Research and Development Process

by

J. C. Rupe

U.S. Army Air Defense Human Research Unit
Fort Bliss, Texas

Under the Technical Supervision of

The George Washington University
HUMAN RESOURCES RESEARCH OFFICE
operating under contract with
THE DEPARTMENT OF THE ARMY

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OFFICE OF THE CHIEF OF RESEARCH AND DEVELOPMENT
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SUBJECT: The Prediction of Training Requirements for Future Weapon Systems

TO: COMMANDER
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ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA
ATTN TIPCR

1. The attached HumRRO Technical Report, subject as above, is for your information and retention.

2. In weapon systems development there is serious concern that hardware development procedures do not provide for the timely insertion of manpower considerations involving operation, maintenance and support of new systems concurrent with entering the inventory. The examination of this problem is the essence of this study.

3. The implementation of the recommendations of this report will require a period of time and the application of much effort in order to realize to the maximum the potential benefits. This report is considered applicable and should be of interest to all agencies concerned with the development of major hardware systems.

4. It is desired that interested agencies review this report with a view toward making recommendations based on local experiences. Recommendations should be processed through appropriate headquarters.

FOR THE CHIEF OF RESEARCH AND DEVELOPMENT:

1 Incl
as

GEORGE J. HAYERLE, JR.
Colonel, GS
Chief, Human Factors and Operations
Research Division

THE PREDICTION OF TRAINING REQUIREMENTS FOR FUTURE WEAPON SYSTEMS,

A Personnel Support System Research and Development Process

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Task UPSTREAM III

COMPOSITION OF RESEARCH TEAM

During the conduct of this study, Dr. Robert G. Smith, Jr., was Director of Research of the U.S. Army Air Defense Human Research Unit and Col. David Cooper was Unit Chief.

Dr. Harold L. Thorgersen participated in the early planning and survey work for this study. Mr. William R. Atchley reviewed the literature and human factors specifications for numerous weapon systems, and is largely responsible for the preparation of the special appendices on these topics (Appendices E and F).

Colonel Cooper and Col. Arthur E. Solem, USA Ret., provided specialized assistance, permitting the author to draw on their years of Army experience in his efforts to give the report the appropriate military orientation.

FOREWORD

This report deals with the prediction of training requirements for the effective and efficient manning of new weapon systems. The systematic procedures described are for use during weapon system research, development, and test. These procedures are functional and should be capable of being incorporated into a variety of Army organizational structures. This report, therefore, does not treat strictly organizational matters.

It is believed that publication of the report is timely. The procedures outlined should be of value to the U.S. Continental Army Command, and perhaps even more so to the U.S. Army Materiel Command and the U.S. Army Combat Developments Command, in their deliberation on how to improve the process whereby machine and man are welded into an efficient unit.

SUMMARY AND RECOMMENDATIONS

MILITARY PROBLEM

The technology of weapon systems is outstripping the capability of our society to supply competently trained manpower to operate, maintain, and support new systems as they enter the inventory. This problem has been a matter of major and continuing concern to the Army in its effort to make the most effective use of the man-and-machine resources available to it.

At a HumRRO Planning Conference on 16 November 1960, Major General Wm. W. Dick, then Deputy Chief of Research and Development, stated,

> We have come to realize that we need to know much more about the most important ingredient in the weapons system—Man. The weapons are useless unless we can motivate and train the man to use them successfully. . . . Intensify your research in the area of projecting training requirements of new weapons systems and reduce it to a methodology with wide application—our research must assure the availability of well-trained men to operate the weapon when it rolls off the assembly line.

General Herbert B. Powell, Commanding General, U.S. Continental Army Command, wrote an article entitled "The Soldier First in Research and Development," in the June 1961 issue of the *Army Information Digest*. Emphasizing that human factors must be given primary attention at all stages in developing a weapon system, he pointed out that

> User considerations in the development of military hardware are almost entirely human factors considerations. When a new piece of equipment is developed, the user is concerned with how many men will be needed to operate it, how much training will be required, how difficult it will be to maintain, how easily men can transport it, how quickly it can be put into or taken out of action, how effectively men can employ it.

PURPOSE OF THE RESEARCH

The purpose of this study was to develop systematic procedures for use during weapon system research, development, and test to assure the effective and economical production of human factors data and products required for concurrent building of a Personnel Support System. The Personnel Support System (PSS) is conceived to include not only the trained personnel to operate and maintain a weapon system but also the basic job data, equipment, and materials required to select and train those people.

This study is concerned only with training requirements and training support materials.[1] The data and products are required by personnel and training agencies for the

[1]In reporting these investigations, it has been necessary to mention activities within the domain of other human factors agencies, as delineated in AR 70-8, *Research and Development, Human Factors Research*. This has been done not with the intention of suggesting any change in their direction or their responsibilities, but to note that the activities of human factors engineering will affect the nature of the basic data, the task and skill analysis which is an important facet of this study. These data in turn may prove useful as sources for the fulfillment of the classification function of The Adjutant General's Office.

timely preparation of training support materials, equipment, and programs. The requirement is to train personnel, in a minimum time following production of a new weapon system, to be capable of performing efficiently the command, operational, maintenance, and support activities imposed by the new system design and the plans and procedures projected for its tactical use.

RESEARCH PROCEDURE AND RESULTS

1. The current "state of the art" for predicting personnel and training requirements during weapon system design and development was determined by a review of the literature.

2. Army, Navy, and Air Force agencies were visited in order to examine their efforts in this area to determine the extent to which available methods are being applied.

3. Current Army practices were further analyzed and compared with the current state of the art for predicting human factors training requirements.

4. Methods were designed to achieve the following purposes:

a. Influence materiel design to bring its requirements for personnel training within the capabilities of the typical soldier. These capabilities are in terms of the basic knowledge, skills, and intelligence he brings with him into the Army and the average length of time he can be expected to remain in the service.

b. Minimize the length of time between production of materiel and achievement of the maximum designed operational capability of the man-weapon system. This is to be accomplished through optimally effective selection, assignment, and training based upon early and accurate prediction of the personnel and training requirements imposed by the weapon system design.

5. For readers interested in a more detailed description of some implementation problems than was considered appropriate for the body of this report, two supplementary sections have been appended. Appendix A presents a structure for providing human factors inputs to weapon system development, discusses the Personnel Support System end products desired, and delineates some problems concerning where and by whom these end products should be developed. Appendix B, "The Personnel Support System Research and Development Process in Operation," presents in chronological order human factors inputs to a weapon system, from the Qualitative Materiel Development Objective stage through all stages of development until the system is in operational use.

CONCLUSIONS

1. The Army has made a substantial beginning in the human factors area of weapon system development over the past several years. However, the effort in this area needs more emphasis and greater scope in order to achieve the required results. (pp. 10-14)

2. The Army has tended to limit its human factors efforts in the direct support of training to obtaining Task and Skill Analyses (T&SA) and Training Aids Feasibility Studies (TAFS) for individually specified weapon systems, rather than directing that such efforts be routine for all weapon systems. (pp. 15-17)

3. The products, T&SA and TAFS, have not measured up to the state of the art in terms of completeness and capacity to independently support other personnel and training processes and products. (pp. 11-14) Two of the reasons why these products have fallen short are:

a. Human factors products have been negotiated and contracted for separately from the contract for the materiel rather than as an integral part of, and a determining factor in, the letting of the materiel contract. (pp. 17-19)

b. Specifications for human factors products have been inadequate in clearly delineating the information that is required, how it is to be developed, and in what form it is to be produced. (pp. 19-20)

4. The Army has not assigned personnel—or been successful generally in having contractors assign personnel—with appropriate human factors professional skills, who are capable of directing the production of data that are basic to the development of training and training support materials. (pp. 20-24)

5. The utility of detailed task analysis data in supporting the accomplishment of the training mission has not been fully recognized. (pp. 29-30)

6. The Army training complex has insufficient operational capability for accomplishing the detailed task analyses required to modify ongoing training programs on a broad scale. (p. 37)

7. The T&SA supplies essentially the same information as the Maintenance Allocation Charts (MAC's) and serves many other vital purposes which the MAC's do not. Great economy could be realized if the objectives of the MAC program were integrated with those of the T&SA program. (pp. 25-28)

8. The Army can achieve marked improvement in the prediction of training requirements, the development of training support materials, and the efficient preparation of manpower on schedule with new weapon system production by adopting and implementing the concept of a Personnel Support System *development process*, to be conducted concurrently and integrated with the research and development of its related weapon. (pp. 31-44)

IMPLICATIONS AND RECOMMENDATIONS

The concept of a Personnel Support System created by a research and development process concurrent with and equal in importance to that for the weapon it is designed to support is only sketched in this report. Similarly, the procedures to be followed in such a development are stated in broad terms and do not specifically cover the multitude of incidental and unforeseeable problems that will continually rise to impede successful implementation.

Consequently, the first consideration, subsequent to a decision to take positive action on the recommendations listed below, will be to obtain appropriately qualified personnel who, while working within the frame work of this general concept, are capable of refining the procedures and resolving the problems incident thereto.

In effect, what this report does is to describe a basic methodology. To refine this methodology to one of wide application, as requested by General Dick, it is proposed that it be submitted to an "operational test." To do this, it is recommended that the following plan of implementation be approved and directed by appropriate Army authority.

1. Operational Test

a. Direct that an "operational test" of the Personnel Support System concept be made for one weapon system about to enter research and development. The test would be conducted under conditions that would exist if the implementation recommendations (under 2. below) were put into effect for all weapon systems. (pp. 31-40)

b. Select and assign personnel with appropriate professional human factors qualifications to key positions in the responsible development, training, and supporting agencies. (pp. 45-46 and 47)

(1) Require the key human factors personnel, as representatives of their agencies, to develop, coordinate, and obtain approval of procedures for conducting interdependent functions and preparing the products of their agencies in "one" place on a continuing basis. This will take place concurrently and integrally with the production by the contractor of task analysis data during materiel R&D and after materiel production as required. (pp. 31-40)

(2) Require these personnel to develop specifications to cover contractor human factors activities in the generation of personnel and training requirements data. These specifications would be correlated with and in support of a human factors clause for inclusion in the basic weapon system contract. (pp. 19-20)

(3) Require these personnel to evaluate and make recommendations regarding the capability of bidding contractors to fulfill the requirements of the human factors clause and specifications. (p. 45)

c. After the decision to implement, take action immediately within the Civil Schooling Program to inaugurate a curriculum of graduate study in human factors. This would prepare the required number of career officer personnel for assignment to subordinate positions in later phases of the operational test. Key professional personnel will be working at all levels to test and refine the procedures, but, without doubt, the volume of work will require additional trained help by the time these officers can be trained. (pp. 46-47)

d. As the results of the operational test make it possible to predict a favorable outcome (the total test will require years if begun at the QMDO stage), take action to direct that the Personnel Support System Research and Development Process concept be applied to the development of all future weapon systems. This would involve the implementation of the following additional recommendations on an Army-wide basis.

2. Implementation

a. Amend AR 705-5, *Research and Development of Materiel*, and all appropriate subordinate documentation in such a manner as to assure the development of Personnel Support System materials, following a specified methodology (pp. 31-40), for all systems concurrently and integrally with materiel research and development. (pp. 15-17) *All* systems are included in this recommendation because insofar as a new system requires materiel research and development (i.e., does not *adopt* current major subsystems), its personnel support system should be systematically developed. (pp. 42-43)

b. Amend R&D Directive 70-21, *Human Factors Engineering in Development Contracts*, to require inclusion of a clause in each basic or prime weapon system contract requiring the development of human factors basic data and certain products based upon them, concurrent to and integrated with materiel R&D but according to separate specifications. Capability to fulfill the requirements of this clause should be one of the critical factors in letting the contract. (pp. 17-19, p. 42; Appendix C)

c. Develop specifications of a nature applicable to weapon systems in general, for use by all Army developing agencies to define procedures to be followed and materials to be produced in support of the human factors clause of the basic contract. These specifications should be applied also to systems developed in Army arsenals. (pp. 19-20)

d. Take steps to provide a supply of officers and/or civilians appropriately trained in human factors technology, for assignments as required to positions in developing and support agencies and in combat arms and technical services schools. (pp. 45-47)

e. Take steps to increase the supply of specially qualified officers by expanding the Civil Schooling Program of graduate study (MA-PhD) to produce officers of the required human factors competence, and provide for maximum use of their training and experience through continuing and consistent assignment. (pp. 23-25)

f. Combine the objectives of the Maintenance Allocation Chart program with those of the Task and Skill Analysis program. (pp. 25-28)

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THE PREDICTION OF TRAINING REQUIREMENTS FOR FUTURE WEAPON SYSTEMS

A Personnel Support System Research and Development Process

Chapter 1

THE RESEARCH PROBLEM

INTRODUCTION

Since World War II, the military services have found that, increasingly, weapon system technology has been outstripping the services' ability to supply competently trained manpower to operate, maintain, and support new systems at the time they come into the inventory. At the least, this imbalance has resulted in extended lag times between the receipt of production hardware and the achievement of the operational capability designed into the system. At the worst, it has caused extensive modification of materiel, less than optimum system performance, or even failure to achieve acceptable system objectives. The sheer pace of scientific and technological advance has been such that some systems had to be cancelled while still under development, and others were approaching obsolescence before personnel became capable of operating and maintaining them at full potential.

It would be a gross overstatement to claim that all problems would have been solved had more attention been given, during system development, to predicting and evaluating information concerning the human tasks arising from the interactions of man and machine. Experience has shown, however, that some of the most difficult and time-consuming training problems have grown out of tasks of such a nature that the difficulty could clearly have been predicted, by professionally trained personnel, from early design drawings of the hardware.

OBJECTIVES OF THE RESEARCH

Great effort and expense are being expended on present and future Army weapons to ensure that the most advanced, pertinent technological state of the art is applied during the period of their design and development. Since similar emphasis has not been given to anticipation techniques relating to the human side of the system, this research was undertaken with the following objectives:

(1) To assess the current state of the art in the human factors area of integrated man-weapons systems development.
(2) To determine the extent of its application to Army systems.
(3) To develop means by which more effective application could be made.

The over-all goal sought by such application is twofold:

(1) To produce weapon systems whose personnel demands are designed to be within the range of adaptability of the typical soldier—the basic knowledge, skills, and intelligence he brings with him into the Army, and the average length of time he can be expected to remain in the service.

(2) To minimize the length of time between production and the achievement of the maximum designed operational capability of the man-weapon system. This would be accomplished through optimally effective selection, assignment, and training based upon an early and accurate prediction of the personnel and training requirements imposed by the design of the weapon system.

BACKGROUND AND IMPORTANCE OF THE PROBLEM

A cursory review of the weapons man has fashioned and used over the ages reveals a startling reduction in their useful lifetime as instruments of war. The club, axe, spear, and bow and arrow were useful for periods of hundreds to thousands of years. In the present century, classes of weapons and even individual models have remained in the active inventory for decades. Today, the weapon system that is not obsolete or at least obsolescent within 10 years is probably the exception.

The simplicity and long life of earlier weapons and tools have permitted the growth of what might be termed an unacknowledged assumption—that the human being is completely adaptable. An attitude that has existed in the past is indicated by the statement: Give me the men and I will find and develop the skills I need. Franklin V. Taylor has stated[1] that engineering psychology (human engineering) began with the intellectual discovery that the human is not a perfectly adaptable organism.

Of course, no one has ever formally asserted that man could adapt to anything—we have just acted as if this were so. For instance, it was taken for granted that anyone could use the lowly shovel effectively. Then, before the turn of the century Frederick W. Taylor, sometimes called the father of scientific management, showed that by adjusting the size of the shovel to the material to be moved and to the individual, the output could be increased many fold.

This illustrates a point frequently overlooked: The final criterion of total system effectiveness is the <u>combined</u> performance of all the components in the system, whether they be electronic, mechanical, or human. It also illustrates that, in even the simplest man-machine relationship, strong interactions may exist between psychophysiological and engineering variables. A finding that has been corroborated repeatedly is that proper attention to engineering variables reduces

[1]Franklin V. Taylor, "Four Basic Ideas in Engineering Psychology," *Amer. Psychologist*, vol. 15, no. 10, October 1960, p. 643.

the dependence of system performance upon selection and training of personnel. Thus, by a variation in engineering (while keeping the mission and capability of the equipment constant), the complexity of the human task has often been reduced to the point where it could be learned by almost anyone from one demonstration.[1]

Any reduction in training time results in the extension of time that can be devoted to productive work. This point becomes more significant when viewed in the context of the current economic, technological, and international political situation. The posture of deterrence assumed by the United States demands the maintenance in being of ready forces competent in the use of the most modern weapons. The increasing complexity of these weapons has tended toward lengthening the training required for personnel to attain competence.

At the same time, the length of service of military personnel continues to be subject to those controls acceptable by our citizenry during peacetime. The percentage of personnel who reenlist or choose military careers is far from being as high as would be desired. Deferment policies, direct commissions, and enlistments in other services have a significant effect in lowering the qualitative level of personnel recruited or inducted by the Army. The percentages of recruits (RA) and inductees (US) entering the Army during the first eight months of calendar year 1960 are presented in Table 1 according to Armed Forces Qualification Test (AFQT) scores.[2]

Table 1

Percentage of Army Entrants by AFQT Category During First Eight Months of 1960

Entrants	Category[a]				Per Cent of Total Entrants
	I	II	III	IV	
Recruits (RA)	8	27	65	–	56
Inductees (US)	7	20	36	37	44
Total	8	24	52	16	100

[a]AFQT Score Category: I, 93-100 Percentile; II, 65-92 Percentile; III, 31-64 Percentile; IV, 10-30 Percentile supplemented by two or more aptitude area scores of 90 or higher.

In the light of these data, it would appear that the Army will have little choice but to staff weapon systems with a goodly percentage of men who are at or near the average in ability level, when and if the Category I and II men are distributed equitably among all its complex weapon systems. Further, the Army can expect not to retain the majority of these personnel for more than one enlistment or induction period.

[1]*Ibid.*, pp. 644-645.

[2]Figures derived from monthly report: *Qualitative Distribution of Military Accessions and Rejections*, The Adjutant General's Office, Department of the Army, Washington, January-August 1960.

And finally, in view of a ceiling on numbers, funds, and facilities, in order to have operational man-weapon systems in being the Army must develop performance capability in these soldiers in some minimal portion of the period of time they can be retained.

This throws the challenge to at least two groups of people: (1) the design engineers and human factors engineers, to combine their talents in reducing the complexity of the human tasks required by the systems they design; (2) the human factors specialists—that is, personnel and training specialists—to develop more effective job aids and increase the efficiency of training through more appropriate devices and methods directly related to the behavioral skills demanded by the job.

To further emphasize that the importance of human elements of a man-weapon system rivals that of hardware elements, the findings of a Stanford Research Institute study[1] on Air Force missile systems should be noted. This study on human engineering testing and malfunction data collection showed that, during launch and prelaunch activities for nine missile systems, human-initiated equipment failures accounted for 20 to 52 per cent of the total equipment failures. Of the total 3,829 usable failure reports, 29 per cent were classified as reports of human-initiated failures, and of 419 hold reports, 20 per cent were classified as reports of human-initiated holds.

It may be said that these results were due in part to the fact that this study covered systems undergoing test rather than those proven and in the hands of troops; on the other hand, it is also true that the level of training and experience of contractor or military personnel conducting such tests undoubtedly exceeds that anticipated for personnel to be assigned ultimately to the systems. Irrespective of the influence, in either direction, of these factors, this study points up the importance of establishing systematic procedures for identifying, analyzing, and thoroughly testing the human tasks that are such an integral part of over-all system design and development.

[1]Albert Shapero *et al.*, *Human Engineering Testing and Malfunction Data Collection in Weapon System Test Programs*, Stanford Research Institute, for Wright Air Development Division, Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, WADD Technical Report 60-36, February 1960.

Chapter 2

THE STATE OF THE ART[1]

PAST RESEARCH

Extensive research has been conducted during the past decade to develop methods for predicting personnel requirements for weapon systems during their development.[2] Most of the research was done by or for the military services. The greater portion of the application of these methods has been accomplished in service and by contract on Air Force systems. The extent of this work, beginning about 1955, was largely responsible for the development of a human factors capability in principal defense contractor establishments. Before that time, this capability was practically negligible; such attention as was given to the human factors area was limited to human engineering experimentation largely concerned with such factors as the dynamics of the design of controls and displays, and their location in the work place.

The current state of the art is due to contributions of innumerable individuals, representing many disciplines, conducting research and/or making applications in the military services, in nonprofit institutions, and in contractor plants. The areas of specialization of those individuals were mainly in industrial and engineering psychology, operations analysis, training, and design and industrial engineering.

The state of the art was summarized in one comprehensive survey of the literature on Air Force research:[3]

(1) Fairly thorough procedures exist for describing positions and tasks. These or some variations have been used extensively. There is no evidence of any systematic attempts to evaluate the procedures to identify their strong and weak points.

(2) A procedure exists for combining tasks into positions. Again, there is no evidence of systematic evaluation of the method.

[1] The Army, Navy, and Air Force agencies visited during the process of collecting information for this report are listed in Appendix D.

[2] See Appendix E for a review of that part of this research having the most significance for this study.

[3] John D. Folley, Jr., Jean B. Fairman, and Edna M. Jones, *A Survey of the Literature on Prediction of Air Force Personnel Requirements*, American Institute for Research, for Behavioral Sciences Laboratory, Aerospace Medical Division, Wright Air Development Division, Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, WADD Technical Report 60-493, July 1960.

(3) Estimating manpower requirements has often been done, but no formal evaluation has been made of its effectiveness.
(4) Determining skill requirements has received little methodological attention. In most cases attention has been directed at the rating of skill levels rather than at any objective determination of requirements.

The lack of systematic evaluations in these areas, as reported in this survey, does not reflect discredit upon either the analytic procedures or the information they produce. The fact that efforts to predict personnel requirements are being expanded on an ever-increasing scale indicates that the products are meeting a recognized need to an acceptable degree. The procedure, scarcely seven years old, has not been used long enough to have achieved its potential effectiveness, to have been practiced frequently enough by competent investigators, or to have been sufficiently tested.

One test report,[1] not included in the above survey, deals with human factors aspects of test objectives for the IM-99A BOMARC system. An objective of this study, of main interest here, was to determine the compatibility of the officially published specialty descriptions with the position requirements for maintenance and operations projected, in part, by an initial Qualitative Personnel Requirements Information (QPRI) study dated September 1956.[2] Of 13 Air Force Specialty Codes (AFSC's) contained in the Organizational Table for the system, the study recommended that only two be changed.

An additional finding of interest was that contractor estimates of the numbers and skill levels of personnel requirements, and of the time required for recycling operations, had been exceedingly optimistic. This was attributed largely to failure of test equipment to perform as reliably and automatically as had been expected. Considerable progress has been made in these areas since 1956, when these predictions were made. It would be well, however, in future studies to seek a balance for the contractors' natural tendency toward optimism by a leavening of military wisdom and experience.

THE CURRENT CONCEPT

The state of the human factors analytic and training art encompasses the following concept: The proficient performance of the human tasks required by an operable system provides the ultimate criterion for all training and the job aids, technical manuals, training aids and devices, and other materials and procedures designed to support it. Tasks come

[1]William E. Powe, Wendell M. Carrier, and Maj. Daniel Skanderа, Jr., USAF, *Human Factors in the maintenance and Operation of the IM-99A System*, APGC-TN-60-10, Human Factors Office, Air Proving Ground Center, Air Research and Development Command, Eglin Air Force Base, Fla., April 1960 (ASTIA Document No. AD 235 950).

[2]Richard W. Highland, *Initial Qualitative Personnel Requirements Information for Weapon System 200A (IM-99 BOMARC)* (U), Development Report AFPTRC-TN-56-116, Air Force Personnel and Training Research Center, Lackland Air Force Base, Texas, September 1956 (CONFIDENTIAL).

into being when hardware is designed. They become as important as reliable functioning of the hardware when their complexity or difficulty, in combination with related or concurrent tasks, threatens to challenge the capabilities of the "average" person available for assignment.

The characteristics of tasks can be predicted, by means of existing tested methods of analysis, from early design drawings, block diagrams, mockups, and similar items, and from consultation with personnel responsible for originating these items. The difficulty of the tasks can be tested in simulated situations in early stages of design and development, just as hardware is tested at these times.

When the level of task difficulty appears to be excessive, it may be reduced by one or more of the following: job aids to reduce the complexity of interpretation or decision making; training aids to improve acquisition of knowledge and motor skills; alternate engineering design solutions that will not compromise system objectives. Thus, a difficult task with complex knowledge and skill requirements may be deliberately "engineered" within limits by adoption of known types of job aids and/or changes in engineering variables. The prediction of the nature of the techniques eventually to be used results from successive approximations, just as with the materiel itself.

Concurrent consideration of hardware and human factors, seeking optimal compromise between the two before production design is frozen, is essential for achieving total system operational capability in a minimum of time from design conception. As both design and task information become more stable, tests of a more realistic type can be conducted to check the adequacy of the task information for its various purposes and to assure that difficulty levels are within required limits.

The equipment design and the job aids that will be used determine what the task will be. Therefore, the nature of the aids must be fully described and clearly conveyed in the body of human factors data. These data should not be restricted to the verbal and numerical; appropriate graphics can be used to clarify the presentation of information in such areas as nomenclature, identification, and location.

The human factors data, taken collectively for a total weapon system, can be sufficiently complete to stand alone in supplying information for determining training objectives, methods, aids, devices, and proficiency measures. Extracting information specific to the different needs of different agencies then becomes, essentially, a sorting, editing, and publishing activity. Thus, from a single source, verified human factors data maintained currently with materiel development may be obtained to serve the specialized needs of Army personnel, training, and using agencies.

The degree to which this concept can be achieved in a timely and economical manner depends, of course, upon the competence of analysts and their supervisors. Even more important, however, are the willing cooperation of design engineering and human factors personnel, the complete backing of contractor top management, and positive, continuous support by the Department of the Army and its developing and training agencies.

THE STATE OF THE ART AS REFLECTED IN AIR FORCE AND NAVY POLICY

The Air Force and, to a lesser degree, the Navy currently require the integrated development of personnel information, and both have sizable in-service forces working on the problem.

The Air Force has the requirement included in Air Force Regulation 5-47.[1] It adds a clause to basic contracts requiring Air Force contractors to develop the personnel information as an integral part of system development. Contractor capability in this area is a critical factor in letting the total system contract. Specifications for each weapon system, based on a standard specification when appropriate, are prepared to support the contract clause.

The Air Force has professionally trained personnel, both civilian and military, to conduct its programs for developing personnel data. Such personnel are assigned to each System Program Office (SPO) and are responsible for directing, monitoring, and evaluating the contractor's human factors efforts in complying with the specifications.

Air Force officers with appropriate qualifications may apply through the U.S. Air Force Institute of Technology for graduate training in selected universities. The training is designed to prepare them for human factors assignments, and graduates are awarded Master of Science degrees. In this manner the Air Force provides professionally trained in-service personnel to augment its civilian professionals assigned to work in this area.

The collective term, "personnel subsystem," is used by the Air Force to indicate the body of trained military personnel required to operate, maintain, and control the integrated hardware subsystems of the weapon system. The subsystem includes many processes and products essential for personnel and hardware integration, among which are Human Engineering, Qualitative Personnel Requirements Information, Technical Manuals, Training and Training Equipment, and a Unit Proficiency System. All of these are covered in an integrated testing program to assure the adequacy and accuracy of all processes and products subsumed under the personnel subsystem.[2] Air Force Ballistic Missile Division (AFBMD) Exhibit 60-1 requires that

> ". . . contractors shall perform the same role in testing the personnel subsystem as established for other subsystems and the complete weapon and/or space systems."

The Navy also has a active human factors program under the Personnel Research Division of the Bureau of Naval Personnel. There are representatives in most of the principal systems development

[1]Department of the Air Force, *Weapons System Documents*, Air Force Regulation 5-47, 29 August 1956 (superseded by AF Reg 375-4, *Systems Management System Documentation*, 20 January 1961).

[2]Air Research and Development Command, *Personnel Subsystem Testing for Ballistic Missile and Space Systems*, AFBMD Exhibit 60-1, Air Force Ballistic Missile Division, ARDC, April 1960.

bureaus and project offices, who are concerned with developing personnel requirements information as an integral part of hardware development. This Division both conducts and supports applied research in obtaining data for new weapon systems such as manpower requirements, duty specifications, and training information for officer and enlisted personnel.

The Navy Bureau of Ordnance endorses the integrated development of training and job performance supports as indicated by instructions for the preparation of ordnance publications.[1]

> It is important to military effectiveness that Bureau of Ordnance technical publications be as carefully 'engineered' as are related mechanisms. . . . This publication advocates a new concept with respect to timely preparation of technical manuals, that work on them be started during the initial stage of equipment development and be continued through evaluation and design stabilization with necessary changes to the manuscript and art being made as the design is modified. In this way, the manual will be completed at the same time as the equipment, and will be available for use when needed.

ARMY EXPERIENCE

The Army has made substantial progress in recent years in the human factors area of weapon system development. The field of human engineering, in particular, has been given considerable emphasis. The Ordnance Human Engineering Laboratory, for example, has been making most effective contributions since it was established in 1952. Emphasis on human factors engineering in the preparation of Military Characteristics is currently being increased by the U.S. Continental Army Command, as indicated in USCONARC Pamphlet No. 705-1.[2]

Human factors engineering does not, however, include the compilation and analysis of all the human tasks involved in operating, maintaining, and supporting a new system. Nor does it include the process of combining tasks into jobs so that their combined impact upon the Army personnel and training organizations can be predicted accurately at the time this information is required for effective planning.

In the course of weapon system development, certain agencies are responsible for considering manpower and training requirements. For some years many officials in the highest Army circles have been concerned with doing this earlier and more accurately, to shorten the lag time between production of weapons and their operational deployment. This concern, coupled with a knowledge of progress the Air Force has made in its QPRI program, led to a beginning by the Army in obtaining personnel information while new systems are being developed.

In the initial efforts to obtain this type of information under contract, agencies within the Army Ordnance Missile Command developed

[1] Navy Bureau of Ordnance, *Preparation of Ordnance Publications*, 3d rev. OP-1, Navy Bureau of Ordnance (now Bureau of Naval Weapons), Washington, D.C., July 1958, pp. v-viii.
[2] See USCONARC Pamphlet No. 705-1, 1 June 1961.

specifications for Task and Skill Analyses (T&SA) based upon an Air Force version used in the 1957-58 period. These were used or are being used to obtain the specified information for the JUPITER and PERSHING systems by contract. Task and skill analyses were obtained on the NIKE ZEUS system,[1] on the basis of a further modification of the specifications and an evaluation of sample products by various using and advisory agencies.[2] A Training Aids Feasibility Study (TAFS) was also conducted for this system to provide task-by-task recommendations for aids and devices to promote acquisition of required skills.

These efforts have been in the right direction and have resulted in substantial achievement. As would be expected, however, a review of the results obtained under the first contracts suggests that considerable improvement is still possible.

The characteristics and usefulness of the products obtained by contract varied considerably between the JUPITER and PERSHING systems even though essentially the same specifications were used for both. This variation is believed to be due primarily to differences in capability of contractor personnel. An added factor is insufficient knowledge on the part of Army monitoring personnel as to the character of products that can be obtained by human factors specialists.

It cannot really be said that these task and skill analysis products do not meet the specifications. The products closely resemble those obtained by the Air Force during the 1957-58 time period. They do include descriptions of jobs that would be required. Usually, however, the descriptions are stated in such general terms that they might apply to any system. For example, a guidance system arriving at a receiving agency would be "uncrated, inspected for damage, <u>tested</u>, and sent to storage"; the important, system-specific characteristics of the <u>test</u> are not given. With such sterile task descriptions repeated for each additional subsystem, the resulting report assumes the proportions of a tome, which appears to have value but in fact does not. This type of information has little usefulness for training purposes. It would seem that such a result could be prevented by providing more precise specifications, a clearer understanding of the nature of the information desired, and closer monitoring to assure that it is being generated.

Progress is already being made along these lines, and the detailed MTR Task and Skill Analysis[3] developed on the NIKE ZEUS system shows great improvement. In the essential sequence of events from beginning to successful accomplishment of a task, this analysis first identifies the task, the cue indicating the conditions necessitating its performance, the accessory equipment needed, and prerequisite tasks. This is followed by a description of the task characteristics which supposedly gives the elemental, step-by-step information needed for

[1]See Contract DA 30-069-ORD 1955.

[2]The analysis was scheduled in the following phases: I, detailed analysis of the Missile Tracking Radar only; II, gross T&SA of the total system; III, detailed T&SA of the total system.

[3]Western Electric Co., Inc., *et al.*, *Nike Zeus Task and Skill Analysis Missile Tracking Radar* (U), December 1960 (CONFIDENTIAL).

accomplishment of the task. Other pertinent information (such as effect on the system, number of men required, time required, frequency of occurrence, hazards and precautions, and skills required) is also provided.

One vital omission in the format of this analysis should be noted. There is no provision in the form to remind the analyst that, for each action that must be performed, he must supply feedback information—the indication, signal, or condition that must exist after successful performance of the described action. Such information is obvious when the task calls for rotating switch "A" to position No. 1. It is not obvious in a statement such as ". . . adjusting specified potentiometers for specific indications on a built-in meter and a lamp indicator."[1] Listing the particular adjustment task, from which this statement was quoted, may be helpful for some purposes, such as planning and noting the need for additional analysis. Giving only partial information under task characteristics, however, could well discredit the total product in the eyes of an evaluator. For instance, if neither the potentiometers nor the resulting indications can be specified, how valid is an accompanying estimate that one man can perform the adjustment in six minutes?[2] It would seem better to simply list the task and note that further information is not as yet available. In this type of analysis, no statement can be considered complete unless it gives the cue for action, the action, and the indication(s) that the action is adequate.

While this analysis is the best that has yet been observed for Army systems under development, there are other instances in which it does not measure up to the state of the art or provide the most useful type of information. Inadequacies of this sort could be avoided by insightful monitorship.

For example, many of the initiation cues for listed troubleshooting tasks are described by phrases such as, "Failure to receive proper indications and response when. . ."[3] or "abnormal light and meter indications noted during tasks"[4]; in such cases the proper and normal indications should be specified. Similarly, many of the characteristics of troubleshooting tasks are stated inexactly: "Attempt to isolate trouble by using lights, meters, and switches on front panel"[5]; "adjust. . . per written procedure"[6]; "use a multimeter and schematic to measure input and output voltages."[7] Such statements contribute little to solving the mystery of troubleshooting. Also, if written procedures are a part of the accessory equipment, they should at least be referenced, and preferably they should form a part of the analysis. Their omission merely leaves another job to be done at a later date. Meanwhile, the task information is too incomplete to provide a basis

[1] *Ibid.*, Task Characteristic, Task No. 0010 014.
[2] *Ibid.*
[3] *Ibid.*, Initiation Cue, Task Nos. 0020 144, 0030 144, 0010 143.
[4] *Ibid.*, Task No. 0020 143.
[5] *Ibid.*, Task Nos. 0020 144, 0030 144, 0020 143, 0010 143.
[6] *Ibid.*, Task Characteristic No. 4, Task No. 0010 014.
[7] *Ibid.*, Task Characteristic No. 2, Task No. 0020 144.

for determining training objectives and planning training method and content. The presentation of more precise troubleshooting information is possible, and at an early stage of equipment development.[1]

The skill analysis portion of this NIKE ZEUS Task and Skill Analysis serves virtually no purpose.[2] The following statements about "skills required," each beginning with "ability to," are representative:

"perform screwdriver adjustment"
"monitor meter"
"follow written procedure"
"open and close standard Zeus drawer"
"follow schematics"
"use multimeter"
"perform task characteristics 1-5 above"
"operate telephone handset"

None of these skill statements yields any information that is not already obvious from the statements of task characteristics or the accessory equipment listed. None would cue a training analyst to give this "skill" special attention, either because it appeared to be critical or because it offered some possibility of economy in training. The requirement for skill analysis should be omitted from the specifications except where a new or critical skill or a certain level of a given skill, that cannot be readily inferred from statements about actions, can be recorded.

Considerable experience has now been acquired by the Army in this relatively new field, and progress with regard to the state of the art is encouraging. Now that the practice of obtaining personnel requirements information has been started for some systems under development, certain agencies (e.g., Army schools) are using the products and are asking for such products for new systems being planned.

It is believed that the stage has been reached where certain factors that would accelerate the rate of progress can be recognized. Some of the more important of these factors will be examined in the following section, to improve general understanding and to seek means for achieving a more effective program.

[1]James P. Rogers and H. Walter Thorne, "The Development and Evaluation of Improved Troubleshooting Manuals," HumRRO Technical Report in preparation for Task MAINTRAIN V.

[2]Throughout this paper skill is defined as an aggregate of hypothetical human characteristics such as knowledges, basic aptitudes, intelligence, personality traits, psychomotor coordinations, etc., that fit together in a particular pattern to produce the behavior.

Chapter 3

INCREASING ARMY PROGRESS IN THE STATE OF THE ART

Experience and observation in obtaining personnel requirements information during weapon system development suggest several areas where modifications of current practices, or further development, would seem to offer considerable promise for achieving a more effective program. These areas may be described in terms of requirements for:

(1) Department of the Army direction that specific human factors information will be developed for all weapon systems.
(2) Integration of the requirement for human factors data into the basic weapon system contract.
(3) Adequate specifications for human factors data, to support a contract clause.
(4) Adequate professional direction in the development of such data (both in service and out).
(5) Willingness to modify or replace established procedures.
(6) Recognition in training agencies as to the utility of the product.

DEPARTMENT OF THE ARMY DIRECTION FOR DEVELOPMENT OF SPECIFIC HUMAN FACTORS INFORMATION FOR ALL WEAPON SYSTEMS

It does not appear to be the general practice to require the development of job-task information as an integral part of weapon system research and development for <u>all</u> systems from the outset of weapon planning.[1] While there have been expressions of intent along this line at lower echelons, it appears that, if a firm policy is to be established, it will need to be directed by higher authority.

[1] This condition apparently continues to be true, as of December 1961. In a USAOMC statement of policy dated 9 December 1960 (letter from USAOMC, ORDXM-MWA to Commander, ARGMA, copy to ABMA, Subject: Training), it is stated (par. 3c): "Accordingly, it is this Command's policy that upon initiation of a weapon system project a Task and Skill Analysis will be conducted." However, in a USAOMC letter dated 27 November 1961 (USAOMC, ORDXR-RME, to CG, USCONARC, Subject: NIKE ZEUS Task and Skills Analysis and Training Aids Feasibility Study), it is stated (par. 5): "It is recommended that the present detailed Phase III Task and Skills Analysis and Training Aids Feasibility Studies requirement from training agencies be cancelled." Subsequent to the correspondence noted here, the Phase III effort was cancelled.

At present, the question of whether such information should be obtained comes up as a separate issue for each system. Each time, the issue must again be debated and human factors must compete for funds traditionally considered to be allocated exclusively for the "more important" hardware development.

At an Engineering Concept Review for the MAULER weapon system held in December 1960, training agencies requested that task and skill analyses and training aids feasibility studies be initiated immediately for this new system and be completed by 1 July 1961. The contractor had begun development work on MAULER some nine months earlier. The training agencies were advised that no FY 1961 funds remained in the project account for this purpose and that, unless these agencies had funds or could obtain them elsewhere, such work would have to be delayed until provision could be made for it in the FY 1962 budget. A detailed task and skill analysis was planned to be initiated during July 1961.[1] It was not included in the basic contract but was subsequently negotiated in a separate contract.[2] Thus, nearly a year and a half elapsed from the time development work on the hardware began before task and skill analysis was to have been started.

The above instance appears to be typical of a common viewpoint in the Army; that is, the tendency is to regard task and skill analyses as a "package" that can be purchased at any time when the funds are conveniently available. Under this point of view, human factors information will cost nothing until a contract is signed calling for it, and it will cease costing anything after the product has been delivered. This viewpoint has a major drawback in that it tends to ignore the basic premise that personnel are an integral part of a weapon system.

Under the pressure of today's accelerated programs and overlapping tests, each successive decision that is made to convert design into hardware, without concurrent consideration of the vital man-machine interaction, reduces the opportunity to make small but significant modifications to relieve task complexity. Giving due credit to the human factors engineers, the result can still be a compounding of apparently insignificant increases in difficulty as one "hard" task is added to another to comprise a job. This may not be recognized until an intensive task analysis is made at that later date when the system is firm enough so that the personnel information will be stable. This "passes the buck" to the personnel agencies for selection and to the training agencies for longer and more complex training. At this stage in development, it is often too late or too expensive to go back and modify the hardware unless it can be proven irrefutably that military personnel cannot successfully operate or maintain the system.[3]

[1]Convair/Pomona, Report No. CR-800-176-002, Contract DA 04-495-ORD 1951, p. 7.1.1. Distributed by USAOMC letter, ORDXM-MWA, Subject: Distribution of Final MAULER Engineering Concept Review Book, 16 December 1960.

[2]Personal communication from Combat Developments and Research, U.S. Army Air Defense School, 17 November 1961.

[3]See General Herbert B. Powell, "The Soldier First in Research and Development," *Army Information Digest*, vol. 16, no. 6, June 1961, pp. 30-31.

To summarize, the task analysis process is a valuable tool in weapon system development when performed concurrently with materiel research and development. There is greater assurance that, when the personnel and training information based upon the integrated treatment is finally released to the appropriate Army agencies, there will be little need for subsequent modification in personnel or materiel elements of the system.

It seems evident that uniform application of human factors techniques to Army weapons would have major advantages. Progress in such application could be greatly speeded by Department of the Army action to modify AR 705-5, Research and Development of Materiel,[1] directing that specified personnel and training information be developed concurrently for all weapon systems throughout their total R&D period.

THE BASIC WEAPON SYSTEM CONTRACT

A second major prospect for more rapid progress lies in modifying the practice of what is, in effect, separate contracting for prescribed personnel and training data. While a clause dealing with personnel matters may be included in current materiel contracts, it is usually general in nature and does not describe a specific product to be delivered at a specific time. Builders of all weapons have furnished personnel information of some kind (e.g., key personnel courses and draft manuals) at some time, but this activity has been secondary to the development of the materiel. When something more comprehensive is desired, such as the request for task and skill analysis cited for MAULER, it is negotiated and funded separately. This course of action can have subtle but very real effects on the quality of the product.

A contractor is unlikely to build a strong, effective, permanent, specialized human factors staff if he has no assurance that the Army will purchase the service or product such a staff has been employed to prepare. Such assurance is not produced by a statement in the military characteristics that the system will require "minimum and simplified maintenance"[2] or "reduction in numbers and skill levels of operating personnel"[3] or "competent, professional human factors engineering."[4] Under this type of contract clause, a contractor is not likely to assemble a human factors staff unless a defined product, such as Task and Skill Analysis, is specified and a separate contract or technical instruction is drawn. If beginning and completion dates are stipulated, the project has a short-term, "one-shot" character.

When action for human factors data is taken separately, rather than in conjunction with the letting of a basic contract, it is

[1]Department of the Army, *Research and Development of Materiel: Army Research and Development*, Army Regulations No. 705-5, 21 December 1959.

[2]*Ibid.*, par. 13c(4).

[3]*Ibid.*, par. 13c(6).

[4]Office, Chief of Research and Development, Department of the Army, *Human Factors Engineering in Development Contracts*, R&D Directive 70-21, 8 December 1961.

understandable that the contractor may organize and staff it separately. This raises dual problems. First, top project management will tend <u>not</u> to give the same importance and emphasis to this effort as would be the case if this aspect had been a vital factor in winning the basic contract. Second, personnel who are professionally qualified in this type of human factors work are not readily available, particularly for short-term employment. This often results in the assignment of inexperienced people when there is no continuity in the contractor's need for a human factors staff.

The lack of emphasis by management on skilled human factors input and the use of inexperienced or temporary personnel have been known to greatly hinder the establishment of cooperative working relationships between human factors personnel and design and production engineering personnel. Harmonious relationships and mutual respect develop most readily when the interdependence of the two disciplines in achieving a common goal is recognized by both. The common goal here is mutual agreement as to the validity of human tasks inferred from the hardware design. Each group should be held equally accountable for adequacy of the final product.

Each contractor should be required to provide in his proposal detailed plans for the development of task analyses and associated training support materials. The evaluation of his proposal should include an evaluation of his capability to carry out these plans. An important factor in this evaluation would be the presence on his permanent staff of qualified human factors personnel, well integrated in the organization's operations, who would be assigned to begin work on the project at its initiation.

The existence of such a requirement would provide assurance to the contractor that the Army not only will accept but will require the expenditure of man-hours for both human engineering and the production of personnel and training information on a continuing basis throughout system research and development. An Army statement of policy to this effect would encourage a trend—noted in the current activities of some military contractors—to include human factors investigation in systems work on its own merit. This often is done with the added hope that the customer will recognize his need for the information resulting from such investigation, even though it had not heretofore been required, and will be willing to pay in a separate negotiation for its organization and publication.

Any uncertainty on this matter should be removed from the outset. All information generated in the systematic development of a weapon should be available to the customer. The expense involved in its generation for both recognized primary purposes and later-recognized secondary uses, should be absorbed on a straight man-hour basis in the basic work agreement. In time such a policy could well convert the trend mentioned above into established weapon system development procedure. Then human factors considerations would be as much a conventional part of over-all system design and development as guidance or propulsion is today.

Note should be made of the tremendous volume of information generated in the building of modern complex weapon systems. Great amounts of this information are lost after it has served its primary purpose because its possible further use, after the system has achieved operational status, was not foreseen. An example can be cited in connection with maintenance. It was found in HumRRO Subtask MAINTRAIN V that designers had discarded information that subsequently was needed by maintenance technicians in order to troubleshoot effectively. For instance, the permissible variation in a chassis output is a specification within which the designer of the chassis must stay. Once he has achieved this goal, however, he has no further need for the precise information as to variation and does not keep it.

The technician who troubleshoots an electronic system—and the man who develops manuals for his use—must know what measurements to make (e.g., the amount of gain to be expected in an amplifier). This information can be obtained by analyzing the circuits involved. In many cases, these same analyses had already been made and decisions reached by designers in planning quality control procedures for the production of the equipment. If the engineering material is not retained for use by the manual developer, this duplication of effort is multiplied by innumerable occasions for troubleshooting. It results from a failure to appropriately organize, record, and distribute this information through the maintenance channels designed for the system.

No doubt additional uses could be made of other types of information in the contractor's possession. In the normal conduct of business, the customer usually receives only the information for which he recognizes a need and is willing to pay. Continuing interaction among different intellectual disciplines provides an environment conducive to discovery of additional uses. The "cross-pollination" of the human factors and design engineering disciplines has proven most productive in recent years.

Inclusion in all weapon system contracts of a requirement for the concurrent development of human factors information and materiel can be expected not only to speed the Army's application of the present state of the art but also to contribute toward its advance.[1]

ADEQUATE SPECIFICATIONS

A third major method for expediting progress in this area would be to increase the adequacy and the clarity of specifications delineating what information is wanted, how it is to be developed, and in what form it is to be produced.

Specifications should supply both parties to a contract with clear, unambiguous data, characteristics, and descriptions of the materials, services, and so forth, which are to be supplied, upon which both are agreed. The products delivered should be subject to objective evaluation to determine whether the terms of the contract have been fulfilled.

[1] A proposed revision to R&D Directive 70-21 is presented in Appendix C.

In an area as new as human factors, specifications having these qualities could well take on the characteristics and volume of an educational program. An alternative to such a detailed presentation is to specify the educational and/or experiential qualifications of individuals who are to interpret, carry out, and/or monitor the activities at issue.

As stated earlier, many individuals on both sides of contracts for predicting requirements for new systems have contributed to the present state of the art. The process has not, however, been developed sufficiently or proven convincingly enough over time so that routine procedures, readily understood by lay personnel, can be described in specifications. All of the Armed Services are actively interested in acquiring specification materials that would increase the accuracy and ease of communication.

A simplified human factors specification aimed at achieving mutual understanding among parties to the contract as to its intent and objectives is appended to this report for consideration.[1] The primary objective in these abbreviated specifications is to define the scope of the work and illustrate the variety of activities required in making and verifying a complete analysis.

In the interpretation of military specifications for hardware, engineering training and experience are necessary. Likewise, with human factors specifications, full understanding of the significance of the requirements set forth or the complexities of the work involved requires personnel who are well grounded professionally in human factors and training technology. Conversely, the specifications must include adequate guidance as to what is desired or expected, if the contribution by professional personnel is to reach its full potential.

ADEQUATE DIRECTION BY HUMAN FACTORS SPECIALISTS

The fourth factor that would promote advance in the application of human factors technology to concurrent development of training information and materiel would be an increase in the amount and the quality of professional direction in its behalf by human factors specialists. This would apply both at operational levels of Army developing and training agencies and in contractors' establishments.

The Air Force QPRI program which preceded Army activities in this field was in the hands of competent human factors scientists. Despite some years of development, the program had by no means settled into proven routine procedures capable of being <u>adopted</u>. The procedures have been and are still being <u>adapted</u> under the careful direction of specially trained, experienced, professional human factors personnel.

The Army personnel who were assigned monitoring responsibilities in the early Army efforts in this field were, in most cases, not human factors specialists; often they were engineers who were assigned this additional duty. However capable in fulfilling the requirements of their regular jobs, and while fulfilling them, these monitors could hardly be

[1]See Appendix F.

expected to have much knowledge of the special pitfalls and difficulties of managing a human factors program. What was needed in order to support specifications that were not adequately "specific" was ability to recognize appropriate capabilities in contractor personnel assigned to the work, specific characteristics of the information they must produce, and when it could and could not be produced. The individuals concerned most probably would agree that they did not have specialized professional insight, and the authority accruing from it. Nor did they have the directive authority to aggressively pursue a program such as this within the context of traditional hardware orientation.

A question may be raised as to why inadequacy in the monitoring agency might not have been offset by professional competence on the contractor's staff. This point was touched upon in the section dealing with short-term, relatively fixed-sum contracts separate from those for materiel. In the absence of a permanent staff of human factors personnel, contractors have tended to assign engineers or to employ persons purportedly, but not really, qualified.

Engineering skills are considered essential for interpreting design and drawing inferences as to behaviors involved in the human tasks required. However, the training typically given engineers does not include a firm background in the behavioral sciences (e.g., sensory processes, perception, learning) which is important in interpreting the psychological significance of task behaviors. Examples from the NIKE ZEUS task and skill analyses, which were produced by engineers without continuous aid and guidance by human factors specialists, were cited earlier (pp. 13-14). The examples quoted may be meaningful to other engineers but they do not tell an Army training analyst or programmer what he needs to know. This is the individual for whom basic job information should be prepared, and it should be so specific that it is not subject to varied interpretation when its complexity must be further reduced for presentation to a trainee.

The active demand for human factors specialists that has developed in the last few years has resulted in contractors' employment of people with relevant basic professional training. Many of these people, however, were without experience in applying the required analytic techniques in a weapon system development atmosphere and were not conversant with results of current military training research. Thus, while they had the potential, they did not have an immediately applicable skill to accomplish, without experienced guidance, predictive task analysis. Some individuals directly out of college or graduate schools, without even the benefit of a supervised internship, have been employed to work in and direct programs in the human factors area. In the absence of knowledgeable guidance, either from supervisors or from a monitoring agency, it is not surprising that the job and training information they have produced has not been maximally useful.

The above statements take on added significance when it is noted that little formal training is offered in our colleges and universities in this specific area. The courses in job analysis are usually limited to cyclical-type industrial jobs in being. They do not cover the prediction of training requirements for tasks that must be combined into jobs to support equipment that is not yet in existence.

While the actual skills involved in task analysis are by no means complex, analysts to date have generally developed them on the job in research organizations or in human factors consulting agencies working on military systems. They have done so under the direction of professionals who, through their experience and familiarity with research in the human factors area of system development and of military training, understand and support concepts much akin to those described in this report.

Once the desired pattern of analysis and the administrative procedures for its conduct are established under experienced direction, the continuing day-to-day analyses can be carried on by personnel without professional human factors status, working with engineers. It is believed that personnel with experience in preparing materials for technical manuals, for example, would be well qualified as task analysts after appropriate training on the job. This would free the human factors scientists for the much broader duties of organizing and coordinating a total effort, constantly evaluating the information produced as to completeness and adequacy, planning and conducting difficulty tests of predicted tasks, developing job aids, determining training device requirements, and similar matters.

Colleges and universities are just beginning to develop programs in the human factors area for professionals called by various titles such as human engineers, human factors specialists, and engineering psychologists. A survey of departments of industrial and mechanical engineering reported by Warren in 1956 revealed that, out of 104 departments responding, only 20 had courses in the human factors area.[1] In no institution was there an organized Human Factors program leading to a degree either in engineering or in some other department. In a later article Warren reviewed the programs of ten universities and concluded that no consistent pattern of training in the human factors area had emerged.[2] From the trends, however, he predicted a pattern for the future: The human factors engineer will be trained in engineering with supplementary courses and experience in psychology and physiology.

A committee of the Society of Engineering Psychologists, Division 21 of the American Psychological Association, is in substantial agreement with Warren in the training it recommends.[3] This committee, made up of recognized experts, considered the nature and professional work of psychologists and related specialists who are active in the broad fields of human factors engineering. They analyzed the qualifications required for such work and outlined training programs that should provide an

[1]N. D. Warren, "Automation, Human Engineering, and Psychology," *Amer. Psychologist*, vol. 11, 1956, p. 531.

[2]N. D. Warren, "Educational Programs in the Human Factors Area," *Human Factors*, vol. 1. no. 2, 1959, pp. 12-15.

[3]Committee of the Society of Engineering Psychologists, "Training in Engineering Psychology," *Amer. Psychologist*, vol. 16, 1961, pp. 171-177.

adequate preparation for specialization in this area. Present training programs were considered to be inadequate, inasmuch as only a few colleges and universities offer any kind of special programs in this area, either for engineers or for psychologists. Thus, many engineers who are now assigned to human factors work have little or no formal training in behavioral science, and many psychologists find that their formal scientific training has not prepared them to apply it to system design problems or to collaborate with engineers.

The attention of this committee has been directed much more toward those aspects of human factors engineering concerned with system design than toward systematic task analysis, the combination of tasks into jobs, and their implications for training and training supports. The Army has followed a similar course of reasoning in assigning human factors engineering responsibility to the Technical Services. This assignment does not, however, include responsibility for task and skill analyses.

While it may be most desirable to combine in one person the skills of two or more professional disciplines in this vital area, it is not essential for the personnel and training specialist, particularly if competent human factors engineers are on the design team. The personnel and training specialist must, however, have professional training and scientific objectivity.

Where combined skills have not been available in individuals in the past, the team approach has been used successfully. This approach brought together on contractors' staffs individuals with such skills as those of design engineers, experimental and industrial psychologists, and operational analysts. Rabideau and Cooper, in a study conducted for WADD, specify knowledge and skill requirements they consider essential for the execution of analytic procedures using such a team approach.[1]

It is exceedingly important to have the appropriate skills on the staffs of contractors; it is equally important to have such skills on the military staffs. At an early stage of its human factors work, the Air Force recognized the need for more competence of the professional human factors type in its officers. A one-year graduate program leading to a Master's degree in Human Factors has been inaugurated by the Department of Psychology in one university. This program was developed by the school in cooperation with the Air Force Institute of Technology and began with the fall semester of 1960. Officers are selected on the basis of interest, scholastic ability, and background and are enrolled in a diversified curriculum emphasizing statistical and experimental methods as applied to industrial psychology and human engineering problems. Following two semesters of such preparation, a seminar series is conducted during the final summer session dealing with, among other things, the prediction of job and training requirements.

[1]G. F. Rabideau and J. I. Cooper, *A Guide to the Use of Function and Task Analysis As a Weapon System Development Tool,* NB-60-161, Northrop Corp., Norair Division, for Wright Air Development Division, Wright-Patterson Air Force Base, Ohio, May 1960.

It would seem most appropriate for the Army to consider something of this nature in its Civil Schooling Program, expanding the present program under which selected officers receive graduate training in psychology. Such training would develop officers professionally trained in the human factors area in sufficient numbers for assignment to Army weapon systems developing and training agencies. The normal flow of incoming officers can not be expected to yield a sufficient supply of men with this specialized background.

The Army has taken a constructive step by enrolling officers in short courses in human factors given at various universities. These courses are generally presented in a few days or a week or more and are valuable for sensitizing officers to problems in this area. However, useful as these courses are for orientation, they can not, in this short period, develop competence in these men to actually perform the specialized work which is involved.

It must be emphasized that broad Army experience is extremely important for people doing human factors work on Army systems. Professional military competence is of course essential to the success of the project. However, it does not, in itself, take the place of formal training in the scientific aspects of human factors work.

WILLINGNESS TO MODIFY OR REPLACE ESTABLISHED PROCEDURES

Tradition has a most important influence on the course of progress. On the one hand, it encourages desirable standardization and eases the burden of training new personnel in the conduct of activities. On the other hand, it strongly resists change and inhibits insight regarding courses of action indicated by evolutionary development.

Officer Careers

Advance in technology has increased weapon complexity, which demands greater technical specialization of troops who may engage the enemy from ever greater distances. Yet, the common image of a soldier is that of physical man in personal contact with the enemy. This attitude is reflected in the management, and particularly the development, of officer careers.

The training, development, and brief varied assignment of officers is traditionally supposed to produce leaders who can manage large masses of men in physical contact with an enemy. This program of experience is still the required course for the young officer with "stars in his eyes." In spite of the fact that only about one half of one per cent of officers currently hold general rank, attainment of this rank is held to be the dominating influence in the direction of officer careers. Specialization or assignment with any hint of specialization outside the traditional "fighting" channels appears to hold a threat of being trapped in a "specialized" cul-de-sac and consequent early retirement.

Now, however, "personal contact with the enemy" is only part of the story, in view of the current capability of one man ultimately to release upon an enemy destructive power equivalent to all that expended during World War II. It is evident that military men must have made and directed many critical specialized decisions and actions to make this possible.

There are a number of technical and scientific areas within weapon system development, including human factors and training, that warrant the highest degree of professional training and specialization of military personnel. Many exceedingly competent officers with such qualifications are in fact in appropriate positions of responsibility today. It is true, however, that many apparently well-conceived actions related to weapon systems have been started by such officers who were reassigned before the results were in. Too often these results, when finally available, have bewildered equally competent replacement officers. To depend upon the civilian specialist for continuity does not seem to be a satisfactory solution, since it is the officer who has the authority and must bear the responsibility for vital decisions.

The long period from conception to stabilization of modern weapon systems, along with their technical and scientific complexity, suggest that consideration be given to (1) relating length of tour to "completion" of project, and (2) relating professional military careers to realistic modern requirements so that the status and reward of the specialist are potentially equivalent to those of the "nonspecialized but combat-qualified" officer.

Existing Procedures

There are many current practices, procedures, and activities that have taken on the inertial qualities of a tradition. Most are required by regulation; at some time, they served a useful purpose but this is not necessarily still the case. The acceptance of a new activity, designed to fulfill other requirements, may be slowed if it duplicates some part of one already in existence. It may be attacked on this account particularly if a different agency is currently performing these duties and views the new activity as a threat to an acceptable state of affairs.

One area of this kind where serious duplication can occur is that having to do with the production of the Maintenance Allocation Chart (MAC)[1] and the Task and Skill Analysis (T&SA). This area, as an example of others that may be discovered through the pending integration of materiel development and logistics, will be dealt with in some detail.

The MAC and its preliminary draft, the Recommended Maintenance Operations Chart (RMOC), are required by AR 750-6. They are part of a maintenance package. In all, this consists of the preliminary draft

[1]The MAC assigns maintenance functions and repair operations to be performed by the lowest appropriate maintenance echelon. See: Department of the Army, *Maintenance Planning, Allocation and Coordination*, Army Regulations No. 750-6, par. 3. 10 June 1957.

MAC's to be included in Part II of the technical manual according to AR 310-3[1]; a preliminary draft list of repair parts and special tools authorized for use in organizational maintenance; preliminary draft(s) of Parts I and II of the technical manual(s); and preliminary draft(s) of Lubrication Order(s).

Preparation of the maintenance package is the responsibility of the technical service that develops or procures an item of materiel for service test. According to AR 750-6, it is based upon the physical review or teardown of a model fabricated during the development cycle. In reality, however, work on the RMOC's may be started long before materiel is fabricated, by studying schematics, blueprints, and so forth, and it is then verified later on the materiel.

Every subsystem, subassembly, component, and piece part is listed on the RMOC. Along with each item, the appropriate maintenance task is indicated by placing the number of the echelon to which it is assigned in columns whose titles consist of tasks in these general terms: service, adjust, inspect, test, replace, repair, align, calibrate, and rebuild. Also noted are the tools, test equipment, and so forth that are required to accomplish the task. In deciding which echelon should make a repair, for example, what is involved in the task must at least be visualized or mentally analyzed—which, essentially, is all that is done.

The RMOC, after approval by the various Army coordinating agencies, is used by technical writers of the contractor's staff to prepare technical manuals. These writers must reanalyze the tasks to describe them in the manuals. Such other documentation as may be prepared on the basis of the RMOC's by other personnel or departments may also require analysis of the same tasks. There is no assurance that all of these analyses will be identical except through lengthy and time-consuming coordination. This could be reduced if the responsibility for the production of the RMOC's and the T&SA were combined in one Army monitoring agency. If they are to be produced by the contractor, a combined, coordinated effort should be required and a single body of basic data used (see pp. 40-42). Since the T&SA provides much more complete information about task activities, it surely offers a more logical basis for technical manuals than does the RMOC. If both are to be produced, they certainly should be used in conjunction for preparation of manuals.

The RMOC provides basic data for logistic planning of requirements for tools, spare parts, supplies, and so forth, and decisions as to the echelon at which they will be stocked. It is also basic to the preparation of the MAC, which is a much abbreviated form of the RMOC. The MAC does not make a breakdown of systems and subsystems into a listing of piece parts. While it may be possible to justify the RMOC as a working paper, the justification for publication and distribution of the MAC is not apparent.

Task and skill analysis (which is not required by regulation) provides a much better, firmer, and more consistent basis for efficient

[1]Department of the Army, *Military Publications: Preparation and Processing*, Army Regulations No. 310-3, 15 May 1956.

and economical training than does either the RMOC or the MAC. This value is in addition to the greater and more immediate influence which task analysis has on system design (see pp. 16-17). It would seem that better and more accurate decisions as to the echelon at which tasks should be performed could be made on the basis of a complete, detailed, verified, and recorded task analysis than on the basis of titles such as adjust, replace, and repair, which appear on RMOC's. In the preparation of T&SA the echelon must be identified, so only those task data appropriate to the agencies responsible for the various echelons will go to them.

From the foregoing it appears that the T&SA is able to fulfill all of the functio of the MAC and of the RMOC except for the listing in the latter of all of the parts, pieces, screws, washers, and so forth. The question rises as to whether the purposes for which such a listing is required might not be served in some more economical manner than by the present independent production effort. The possible use of the contractor's parts list should be studied in this regard. The optimum determination on this score could not be made during this study.

The question does seem worthy, however, of careful study by the proponents of both RMOC and T&SA, with the goal of satisfying genuine needs most efficiently. The solution might be the elimination of one or the other, or a combination of the two into a single effort to avoid duplication. It should not be decided simply that T&SA duplicates the RMOC-MAC and therefore is not needed inasmuch as the latter are already required by Army regulation. It has been shown that T&SA does largely duplicate the RMOC-MAC. It cannot be shown, however, that the reverse is true; that is, the RMOC-MAC does not supply all of the information provided in the T&SA.

The magnitude of the economy that might accrue from combining the T&SA and MAC programs can be demonstrated by referring to the experience with the NIKE ZEUS. The MAC program for this system was funded at one time on a ratio of about 4 to 1 for the T&SA program.[1] Since these figures run into seven digits, they are truly significant. The ratio became even greater with the decision not to continue Phase III, the detailed T&SA for the total system, and to rely instead on T&SA Phases I and II, the MAC, and other substitute documentation. This action was taken against the wishes of Air Defense School personnel, who had been very closely involved with the contractor T&SA effort. The decision was based largely on the fact that the MAC's for ZEUS had already been contracted for and the activity was being pursued in a different contractor department when the requirement for T&SA Phase III was established.[2] Had this been the integrated effort described in this report, the T&SA would have assumed its appropriate place in the overall system development plan and the MAC's (RMOC's) would have been

[1]Personal consultation with the ZEUS Division, Combat Developments and Research, U.S. Army Air Defense School, 17 November 1961.

[2]See USAOMC letter ORDXR-RME to CG USCONARC, Subject: NIKE ZEUS Task and Skill Analysis and Training Aids Feasibility Study, 27 November 1961.

developed without duplicate generation of information which the T&SA can better supply.

Before leaving this subject it should be noted additionally that equipment test specifications are considered part of the MAC "package" although not of the MAC itself. Knowledge of these specifications is unquestionably essential for effective job performance. However, the test specifications tend to change, for a number of reasons. They can not be stated precisely until late in system development. They often are prepared as a checklist or job aid instead of as information that must be learned and retained. Thus, it may not be economical or desirable to include test specifications in the main body of the T&SA information that could be useful for conducting training before stabilized data can be determined. It is possible to train individuals how to perform certain check and adjustment tasks without specifying the exact tolerances that must finally be achieved. There does not appear to be any overpowering reason, however, why the test specifications could not be a part of the T&SA "package" instead of part of the MAC "package."

Training Content

A third area affected by tradition is that of training content. Far more emphasis in training is currently given to system, subsystem, and component functioning than can be justified by a careful examination of the human behaviors and the specific knowledges required by typical operator and maintenance jobs.

Such "training" is commonly justified on the grounds that personnel will be more highly motivated and perform their tasks more willingly and effectively if they fully understand how everything works. It is also argued that they will be able to solve unforeseen problems if they know the theory on which certain functions, such as propulsion, guidance, and hydraulics, are based.

While there is, no doubt, some merit in these views, the extent to which this type of "training" is needed and can be afforded warrants closer examination. This approach should be examined in terms of (1) effectiveness in achieving satisfactory task performance, and (2) cost, considering the average length of service and the qualifications of a typical trainee. The theoretical subjects are undoubtedly of value in the "education" of engineers, who may apply their knowledge to the design and development of new systems and who may design, test, and prove steps of procedures. Once proven, however, these procedures can be followed by personnel with less fundamental training and qualifications. Performing the specifics, once they are established, becomes the objective of "training."

Herein lies a commonly recognized difference between education and training. As Crawford[1] has put it, the term <u>training</u> is appropriate for the circumscribed job in which emphasis is on precision of act,

[1]Meredith P. Crawford, "Research and Development in Training and Education," paper read at Symposium on the Contributions of Military Research to Education and Training, Northwestern University, December 1959.

immediate response to a need or command, and predictable outcomes of activity. The term education denotes learning for jobs which are much less circumscribed in content, activity, or responsibility, and in the performance of which the outcome is much less foreseeable.

The Army has depended largely upon engineers to estimate the knowledge requirements new equipment will impose upon operator and maintenance personnel. Their estimates have tended to be subjective and to reflect the subject matter attendant on their own "education," which is heavily weighted with general function and theory. A careful, objective analysis of the behavioral aspects of the tasks required in an operational environment will make apparent their difference from those required for designing and building the subject hardware. In addition, such analysis identifies the minimal knowledge supports that must be supplied by "training," to enable an individual to respond successfully to specific situations he has not encountered before.

Since training cannot be extended endlessly to cover the total universe of tasks in all their variations, knowledge must form the connecting link between correct responses and the range of stimuli that may evoke them. In order for a knowledge to be effective and appropriate for inclusion in "training," it must be such that a job incumbent can (1) discriminate the job situation calling for the knowledge, (2) remember the knowledge content, and (3) make some job-oriented response as a result of recalling that knowledge.[1] Any break in these three links indicates nonoperative, ivory-tower knowledge.

In the absence of complete task and skill analyses that specify otherwise, MOS specifications (see AR 611-201[2]) and training content emphasize the requirement that trainees be firmly grounded in function and theory. This approach has become so customary that training people have tended to reject job data that do not include such materials. This aspect is discussed in the following section.

INSIGHT IN TRAINING AGENCIES AS TO THE UTILITY OF THE PRODUCT

Finally, rate of progress in the procurement of more effective training data would be improved if training agencies acted to establish the demand for these data, and to recognize and specify the nature of information that could more effectively support accomplishment of their mission. Failure to take this sort of action is due in part to the effect of organizational inertia as noted above and in part, no doubt, to a lack of familiarity with research that has proven the effectiveness of training based on task analysis. As a result, much of the early QPRI and

[1]Robert B. Miller, "Derivation of Skills and Knowledges in Electronic Maintenance," in *Symposium on Air Force Human Engineering, Personnel and Training Research*, Publication 516, National Academy of Sciences—National Research Council, Washington, D.C., 1958, p. 60.

[2]Department of the Army, *Manual of Enlisted Military Occupational Specialties*, Army Regulations No. 611-201, 15 June 1960.

task analysis data has been rejected, irrespective of quality, by training agencies of all the military services. Various reasons can be given, including:

(1) It did not conform to what they had been getting, usually by their own efforts, and which they were still getting anyway.
(2) It was produced by someone or some agency other than their own and not at their direction.
(3) It was very detailed and covered much material they already knew how to teach; their instructors could fill in the detail without its being spelled out for them.
(4) They had no confidence in the information until they could verify it themselves on finished hardware.

Such reactions represent the common resistance to change, and awareness of the work and risk involved. They also indicate a lack of comprehension or conviction on the part of those who might direct that personnel be trained and organized to operationally test the building of programs based on such information.

SUMMARY STATEMENT

Complete and detailed analysis of tasks is needed in order to promote understanding of their behavioral aspects, reduce their complexity by incorporating properly designed aids, specify only the essential knowledge requirements, provide all possible pre-solutions by experts, and assure that no important step has been omitted.

Properly organized, task analysis data define job performance objectives from which training objectives may be derived. They provide, essentially, a complete universe of proficiency test items. And they are the basis upon which training conducted by numerous instructors can be standardized and checked for completeness, down to the finest detail desired.

Progress could be enhanced and speeded by appropriate, authoritative directive and by implementation of proven procedures by personnel professionally competent to resolve details of their application, which are too numerous to anticipate or to cover in this report.

Chapter 4

AN APPROACH TO THE DEVELOPMENT OF A "PERSONNEL SUPPORT SYSTEM"

FUNCTIONS OF A PERSONNEL SUPPORT SYSTEM

A report such as this is not the place to suggest how the Army might modify formal organization to more effectively apply human factors state-of-the-art procedures to the over-all problem of supplying trained personnel to operate and maintain new systems as they are produced. It is, perhaps, more appropriate to describe the functions involved in accomplishing this goal, note their interrelationships, and indicate means by which responsible agencies might achieve improved results in carrying out these functions.

To supplement the material in the text for readers interested in a more detailed description of some implementation factors and problems, two appendices have been prepared. Appendix A presents a structure for providing human factors inputs to weapon system development, discusses the Personnel Support System end products desired, and delineates some problems concerning where and by whom these end products should be developed. Appendix B describes the Personnel Support System in operation, presenting in chronological order human factors inputs to a weapon system, from the Qualitative Materiel Development Objective stage through all stages of development until the system is in operational use.[1]

Describing the functions served by the human factors data must, of necessity, be oversimplified. However, the principles may be made clear by tracing a single complex task from its origin on the equipment drawing board to its final incorporation among the capabilities of a proficient Army operator or technician.

Analysis of Task Requirements

As the design for an item of equipment takes form, the task or tasks required to operate and keep it operating also take form. Before

[1]Readers making a more thorough study of the total field of system development, with emphasis on man's part in it, will be interested in a book which was released shortly before this report went to press: Robert M. Gagne (Ed.), *Psychological Principles in System Development*, Holt, Rinehart, and Winston, New York, 1962. This book is the first of its kind to bring together an integrated psychotechnology of system development and is the work of some of the most widely recognized experts in their field. Persons who might be assigned responsibility for implementation of recommendations made in this report would find this book useful.

a prototype is built, the design is examined from a number of viewpoints to make sure that it will accomplish its objectives. Varied design and production engineering viewpoints must be considered; the viewpoint of the human factors engineer should be included.

Among other things, design review should cover (1) the provision for displaying the cue that will indicate the task is to be performed, (2) the mental and/or motor act (response) involved, and (3) the signal or condition that will exist to indicate that the task has been performed satisfactorily.

Assuming that the design is approved, the task required by this design will be firm, but the task required of the performer will depend upon more complete analysis. This analysis would examine the cue-response relationships to determine the knowledge required to establish the correct association and the nature of the psychomotor coordination, if any, required to make the proper response.

Knowledge Requirements

In some troubleshooting tasks there may be only one correct cue-response association to be identified out of a possible ten thousand or more. The knowledge required to enable a man to quickly choose the right one in such cases is immense and, on the basis of experience, impossible to implant in the typical trainee. The knowledge requirement can, however, be reduced by a pre-solution of such problems through comprehensive analysis and a systematic organization of the solutions into a job aid. The response association to innumerable cues would then be the same—reference to the job aid. From this aid, a succession of new cue-response associations would lead the maintenance man through appropriate detailed tests to the final successful "equipment-required" task response.

Knowles[1] has said of this type of task, "The alternative to detailing tests beforehand, which is a designer's task, is to require a highly skilled man to work out the logic on the spot. Thus, operator (maintenance) skill is traded for design skill." As stated earlier (see page 19), these analyses are frequently made and decisions reached in planning quality control procedures for the production of the equipment. It seems entirely appropriate that the analyses be made early in the development phase by highly qualified engineering personnel; they could then be used to support maintenance during the various engineering and user tests of the system. This would permit the procedures based upon these analyses to be tested, verified, and established. Consequently, the eventual user and field maintenance man would not have to be trained to duplicate the engineers' task but, more simply, to follow the procedures

[1]W.B. Knowles, *Automation and Personnel Requirements for Guided Missile Ground Support Functions*, General Electric Company, for Aero Medical Laboratory, Wright Air Development Center, Air Research and Development Command, Wright-Patterson Air Force Base, Ohio, WADC Technical Report 59-240, May 1959.

developed by them. This would definitely tend to lower selection factors and training costs.

One of the most frequently stated objections to making analyses early is that the equipment will change before it reaches the production stage. The objectors do agree that equipment parts, combination, and configuration are the origin of tasks and their characteristics, but they fix their attention upon the several thousand items that may be changed rather than the several hundred thousand that remain unchanged from the beginning. Furthermore, a large percentage of the hardware changes that are made do not change the task characteristics in any respect.

The "nonfinal" status of the equipment is in fact essential to fulfilling one of the purposes of early task analysis—that of identifying appropriate changes in equipment that would reduce task complexity. Modifications of this nature that can still be made "on paper" are much more likely to be accomplished than they would be if suggested after the system has reached the production stage. In production, the cost of changing just the affected engineering drawings could amount to many thousands of dollars.

Motor Skill Requirements

Analysis of tasks, inferred from early design, reveals their psychomotor characteristics. These characteristics, described in behavioral terms, can be evaluated against experience in training as to the criticality and the difficulty of acquiring such a skill. Such a review may suggest the need for and characteristics of training aids and devices to effectively inculcate the skill in trainees. This process provides the earliest equipment-oriented information on which to base requirements for training devices with any degree of validity. If this process is not followed at this stage of system development, the training devices that may eventually be procured will most likely be behind schedule and/or not specific to the skills they are supposed to train.

The current development process as described in AR 705-5 directs using agencies to submit requirements for training aids and devices when submitting Qualitative Materiel Requirements (QMR's) and Military Characteristics (MC's) to the Department of the Army for approval. Presumably this procedure should assure their development on schedule with the parent system and assure that funds are budgeted for their procurement. However, the only kinds of training devices that can be predicted at this early stage of development are those with which to orient personnel in over-all system operation or inert devices for handling and checkout training.

These nonspecific types of trainers are requested largely because they have been used with some degree of success for past systems and because no information exists at this stage on which to base anything more specific. There may be ample justification for such trainers. The training objectives for them seem clear—soldiers need to know how the whole system works and a rugged, safe version of a round may be appropriate for handling and checkout training. The characteristics of trainers to achieve these objectives are outside the scope of this report.[1]

What should be made clear is that the nature of trainers to teach specific skills cannot be predicted until the characteristics of those skills are determined by a careful and thorough analysis of the tasks and jobs demanding those skills. If trainers of this type are required, their development on schedule with the total system has the best chance of being achieved by conducting the task and skill analysis integrally with system design and development.

Training Objectives Derived From Task Requirements

Training objectives constitute the goals of a training program and are composed of detailed statements of what students should be able to do and what they should know at the completion of training. In order for such statements to be relevant, specific, and correct, they must be based upon an accurate determination of task requirements.

The statements of training objectives will, however, differ from the description of task requirements in several ways. Certain job actions may be so common as to exist in the repertory of all trainees or so simple as to be learned readily in on-the-job training. Further, it may not be economical or efficient to utilize formal training to develop in trainees the level of skill ultimately required on the job. This amount of formal training will not be necessary if oportunities for skill practice will be provided after assignment. It is extremely rare for new graduates to be made solely responsible for completely proficient job performance. Rather, it is commonly expected that they will be able to perform correctly but will gain in skill level with experience on the job.[2]

The critical difference between descriptions of task requirements and training objectives is that each objective must be stated in such a way as to permit the measurement of its attainment. This is relatively simple where the required behavior is overt or readily observable. It is not simple in the case of mental activity. Here the manner of making the behavior overt, and thus measurable, must be specified in the statement of the objective. A set of statements of training objectives can be considered as a set of detailed specifications for a test to cover everything a trainee should be able to do upon completion of training.

Once training objectives have been established, they will provide a firm basis for determining course content and will probably be helpful in sequencing course content.[3] They will serve as guidelines to guard

[1]For more information on this subject see: John D. Folley, Jr., *Human Factors Methods for System Design*, AIR-290-60-FR-225, American Institute for Research, Pittsburgh, 1960, pp. 217-326.

[2]Department of the Army, *Army Training Policies*, Army Regulations No. 350-1, 24 May 1961, par. 17c.

[3]For more detail see: Arthur J. Hoehn, *The Development of Training Programs for First Enlistment Personnel in Electronic Maintenance MOS's: II. How to Analyze Performance Objectives to Determine Training Content*, Research Memorandum, Training Methods Division, Human Resources Research Office, January 1960.

against the omission of relevant content and the inclusion of irrelevant content. The selection of course content implies, to a large extent, the choice of those items that are to become a part of the learned knowledges and skills of the graduate of the course. The following criteria are suggested for making such choices:

(1) Items are used frequently on the job (e.g., using a multimeter).
(2) Items require a practiced smoothness, precision, or speed (e.g., manual tracking on radar).
(3) Items require a complex or difficult perceptual discrimination (e.g., taking messages in Morse code).
(4) Items are required only for infrequent situations, but a high speed of response is critical (e.g., first aid procedures)

The remainder of the information required for satisfactory task performance on the job must be made available in technical manuals or other job aids.[1] Some suggested criteria for such items are:

(1) Items are difficult to learn or remember because of the sheer number of details involved (e.g., specific value of each resistor in an electronic system).
(2) Items are the product of the integration or collation of a great multitude of other items (e.g., selection of nuclear warhead for a particular target when many choices are available).
(3) Items are seldom used on the job (e.g., procedural tasks for the recycling of nuclear warheads).
(4) Items can be derived from other items, but the risk of error during derivation or the time required for derivation is intolerable in the operational situation (e.g., tolerance value at a specific point in an electronic system).

Frequently, an item of information required for on-the-job performance is, in the judgment of training analysts, not appropriate for inclusion in the to-be-learned category. This means, ipso facto, that it must be included in the technical manual or another job aid. In such an event, the problems of coordination can be greatly magnified when the responsibility for training content and the responsibility for technical manual preparation are held by different and geographically separated agencies. The problems could be alleviated if all concerned agencies were to use the same criteria for categorizing task support data. They could be even more effectively resolved if, in addition, the coordination took place on a continuing basis in an integrated action at the point of origin of the task analysis.

Training Methods to Exploit Principles of Learning

Immediately after relevant content for training is selected, it is appropriate to choose the method or methods of presentation by which

[1]For more information see: A.J. Hoehn and A.A. Lumsdaine, *Design and Use of Job Aids for Communicating Technical Information*, AFPTRC-TR-58-7, Air Force Personnel and Training Research Center, Maintenance Laboratory, Lowry Air Force Base, Colo., January 1958 (ASTIA Document No. AD 152 109).

the required knowledges and skills may be most effectively incorporated into the repertory of the trainee.

Training devices, which provide for learning by doing through practice, may be considered as one method. The projecting of requirements for such items has been mentioned earlier. The most effective devices have, by their nature, and incorporated in their design, the means of applying three well-established principles of learning:[1]

(1) The trainee or learner must participate actively and continuously in the learning process. Thus the device must provide questions to answer, problems to solve, job actions to practice, and so forth.

(2) The trainee must be supplied with reinforcement. As the term is used here, it refers to the provision of feedback to trainees immediately after the completion of individual activities. Receipt by an individual of information regarding the correctness of an activity he has completed will tend to ensure that he will perform this activity correctly in the future. Thus the device must provide reinforcement that is positive, immediate, and as frequent as possible.

(3) Provision must be made for individual differences in learning rates. Any training method (or device) that does not allow for these individual differences will, by gearing the rate of presentation of material at some arbitrary level, lose some students because they cannot keep up with the pace, and will lose others who become bored and indifferent because the class is moving too slowly.

In most military training programs, the lecture or conference method, the practical exercise or laboratory method, and the demonstration method have, singly or in various combinations, been the methods most commonly used. A cursory examination of each of these methods, in relation to the three principles noted above, reveals that they do not make adequate use of one or more of these principles unless a student-instructor ratio near 1 to 1 is assumed.

Recently the concept of "programmed learning" used in the "automated instruction" or "teaching machine" context has received considerable attention from personnel concerned with training and training research. A major reason for this interest is that this technique provides for trainee participation, reinforcement, and consideration of individual differences substantially more effectively than any of the more conventional training methods.[2]

As the results from research on programmed learning come in, the nature of the types of training content for which it is best suited

[1]For more detail see: R.M. Gagne and R.C. Bolles, A Review of Factors in Learning Efficiency," in *Automatic Teaching: The State of the Art* (Eugene H. Galanter, ed.), John Wiley & Sons, New York, 1959, Chapter 2, pp. 13-54.

[2]For more information on this subject see: Robert G. Smith, Jr., *Teaching Machines and Programmed Instruction--Some Factors to Consider in Implementation*, Research Memorandum, U.S. Army Air Defense Human Research Unit, Fort Bliss, Texas, August 1961.

will be determined and catalogued. Enough is known today, however, to make a beginning in use of this method. This should be considered for new systems just entering research and development for which a systematic, integrated development of the personnel support system, on the order of that described herein, is directed.

Testing Program for Training Quality Control

One final activity is related to the task performance that is determined in the process of task analysis. This is the specification of how, and against what standard of proficiency, the trainee will be measured to permit his graduation and to assure his development to a minimum required level of capability after assignment. To ensure that training is taking place and that it is the desired training, the human behaviors resulting therefrom must be measured against those required by the job. So it is that performance tests, based upon a description of job requirements modified with respect to degree of proficiency by training objectives, should be developed for administration to those presumed to be ready for graduation and assignment. The tests need not be developed where the training is given. Time can be saved if they are devised when and where the basic information is available.

APPLICATION TO CURRENT SYSTEMS

It has been suggested previously that application of the personnel support system concept be started for new systems entering research and development. While this need not be the only beginning, it is believed most effective and economical because complete, detailed task analysis data are essential for a clear understanding of the materials to be learned. Little, if any, information of this sort is available for current weapon systems, and there is currently no operational capability in the Army training complex for accomplishing this type of analysis to modify ongoing training programs on a broad scale. In order to apply this concept to systems in being, provision would have to be made for developing operational capability in this area.

THE PERSONNEL SUPPORT SYSTEM

The foregoing has been an attempt to illustrate the involved and interrelated functions that must be carried out, at some time and place and in some order, to produce a complete training program ready for presentation to trainees. Traditionally, they are carried out by different agencies at different times, in different places and with varying degrees of thoroughness. Then they are coordinated with varying success.

Such a system tends to foster duplication, delay, and, to some extent, unnecessary expense. If the work of one agency is dependent upon the product of another, the first agency must either wait (delay) or generate the product itself in some measure (duplication). Formal coordination of materials that must serve the needs of several agencies is, of course, necessary. However, reduction would be possible in printing costs caused by extensive change in the materials, and in time, travel, and error costs caused in resolving differences among agencies. This could be brought about by the development of clearer, more definitive criteria to guide the decision-making processes, which cover such things as the distribution of tasks to MOS's, and echelon of maintenance. This modification would, hopefully, tend to assure that decisions made at the working levels would be accepted at higher, authoritative levels to a greater extent than is now the case.

Except for the administration of training, most of the functions and products required to develop a complete Personnel Support System are illustrated in Figure 1. When these are viewed collectively and their interdependence noted, it seems pertinent to ask why they are done one at a time and, in some cases, in different places. It should be possible to accomplish them more effectively for one system all in one place in one continuing, integrated process. Materiel is developed in essentially one place (prime contractor or arsenal) in an integrated research and development program. The human system to support it should also be viewed as the research and development process it truly is and developed in "one" place. Where, then, is the most appropriate place?

Task analysis data, which provides the information basic to all the functions and products discussed above, is itself derived from two sources: The design of hardware and the military procedures prescribed for its use. These two, irrespective of their origin, come together by way of a Developing Agency at the establishment of a selected prime contractor or at an arsenal. This would seem to be the most appropriate place to "establish a procedure for exchange of information and a common understanding among the developing agency, using agency, supporting agency, and the contractor on all matters of mutual interest in development projects."[1]

Under such an arrangement, task analysis data could be acted upon directly by the required skilled professionals—contractor and/or military—instead of having to be developed in blocks, printed, and distributed. For that matter, the task analysis does not need to be printed and distributed as a formal document at all. It is a working paper and, when it has "fathered" its end products, it ceases to have other than historical purposes that can be met by the original file copy.

In "one" place timely, coordinated, and integrated action could be taken on the specific weapon system human factors "development project" to produce the materials, which could then be applied in the personnel and training agencies. Results of the application (feedback) must be available to the developer. This means that capable, experienced representatives of the user (training agency) must be on the human factors development team. An organization of the work such as

[1]AR 705-5, 21 December 1959, Par. 11b(5).

Interdependent Functions and Products Required to Develop a Personnel Support System
(Except for Administration of Training)

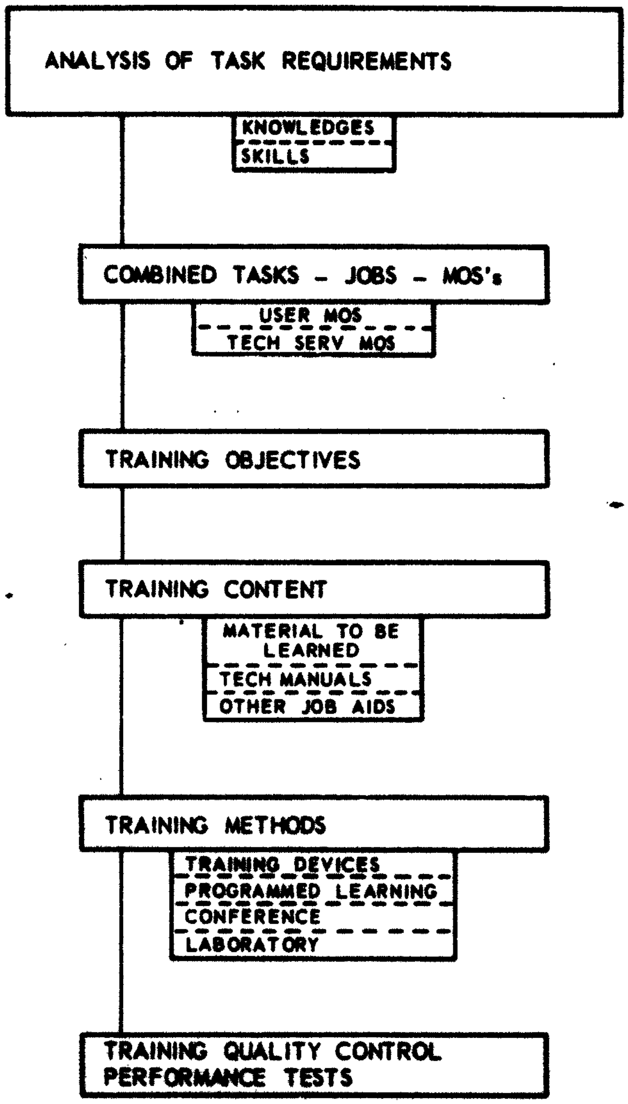

Figure 1

A Model for Developing the Products Required to Build a Personnel Support System

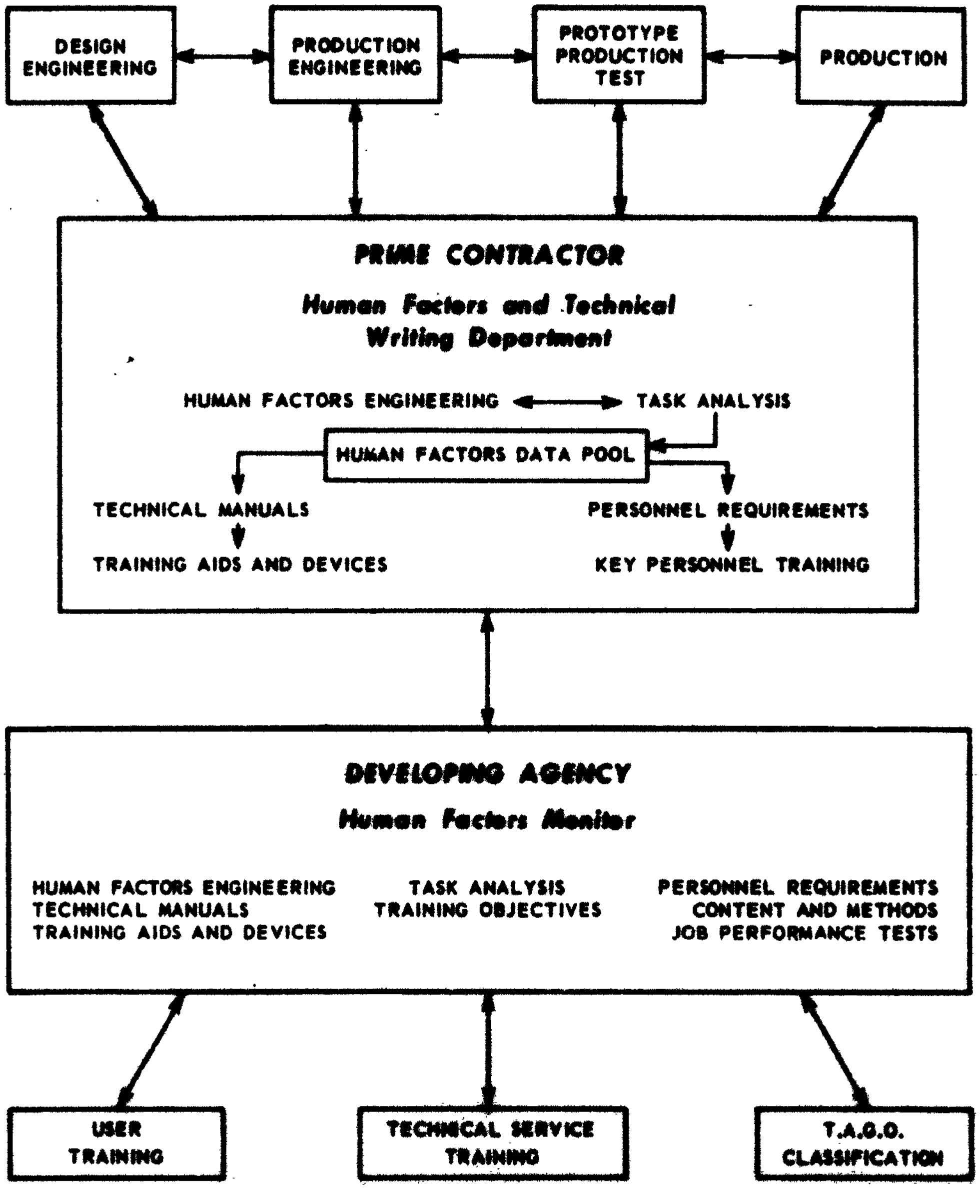

Figure 2

this would greatly facilitate the application of user guidance that General Powell was referring to when he said ". . . user guidance in the design of military equipment is primarily concerned with applying human factors to equipment design."[1]

One way in which the various functions and activities could be carried out is illustrated in Figure 2. It should be noted that this model carries no suggestion for a change in the assignment of responsibility for the indicated functions. Rather, appropriately trained representatives of the currently responsible agencies would be assigned to carry out working, monitoring, and coordinating activities as required to achieve each critical part of a total integrated Personnel Support System. The requirement for working at the developing agency or in the contractor's plant could easily vary from occasional visits to full time, depending upon the particular function, product, or phase of development.

Figure 2 is intended to illustrate some but not necessarily all of the important agencies, activities, and information flow that might be involved in the human factors area of a typical weapon system development. To further clarify the illustration, the general missions of the Human Factors Monitor—who is, of course, only one member of a total developing agency project team—and of the Human Factors Department of the contractor will be summarized.

<u>The Human Factors Monitor</u>. This individual would have the following duties and responsibilities, beginning at the early design phase and continuing throughout system life as required:

(1) Assure the development of human factors information designed to meet specifically, or be basic to, the differing needs of the various personnel and training agencies.
(2) Develop the means, contract specifications, work statements, exhibits, and so forth, within an over-all directive and specification, that may be required by the nature of the particular weapon system for obtaining the human factors information.
(3) Train, direct, and coordinate the activities of subordinate personnel and those representing other Army personnel and training agencies in accomplishing their assigned duties.
(4) Provide contractor human factors personnel with military information, such as operational, maintenance, logistic, and training concepts, plans, and procedures, that will control, affect, or modify the human tasks required for effective weapon system performance.
(5) Monitor contractor work in this specific area as needed to ensure complete understanding of the contractual requirements, and effective progress on schedule, and to avoid duplication of effort.

[1]*Op. cit.*, p. 33.

The Prime Contractor's Human Factors Department. The prime contractor must demonstrate a human factors capability and have qualified personnel responsible for conducting function and task analysis according to the specifications. These personnel will:

(1) Maintain in a central data pool (or have knowledge of the repository for technical data required for specific purposes) data that are always current with the stage of system development.

(2) Evaluate system, subsystem, and component design proposals from Design Engineering in terms of Army personnel capabilities, and propose or accept compromise proposals to reduce the complexity of tasks and the training to support them. They will, of course, follow these proposals through subsequent development and production phases.

(3) Conduct tests at appropriate times to determine the accuracy and adequacy of the task analyses and task difficulty in terms of performance capabilities of typical Army personnel.

(4) Be responsible for the validity and uniformity of the information released to the Army in whatever form is required—training, technical manuals, and so forth. They will do this by making certain that all such materials are based upon a single body of task data maintained current with the stage of materiel development.

The prime contractor will ensure that equivalent human factors data are generated by subcontractors to cover subsystems they develop, inasmuch as these data may be independent of the overall system. However, he will be responsible for generating those data dealing with the interface and with the integration of all data into the central data pool.

Traditionally, contractors have been responsible for providing key personnel training. The data to support this training will be drawn from the central data pool.

A LOOK TO THE FUTURE

If procedures such as those discussed herein are adopted, refined, and become routine, it seems entirely conceivable that considerable economy may be effected over current practices. With the functions of the numerous agencies centralized, there presumably would be less likelihood of duplication or inadvertent multiple payment to contractors for essentially the same information or products. Such duplication can occur, as, for example, when different agencies contract separately for items stemming from the same basic data. Items such as technical manuals, training for key personnel, and data for personnel specifications and MOS descriptions are generally developed by different contractor departments—Technical Writing, Customer Training, and, possibly, Human Factors.[1] It would not be unusual for each department to generate the "same" basic data in support of their different end products. This not only increases the cost but offers a likely source of subsequent confusion if the basic data do not turn out the same.

An objective may be raised to the effect that task and skill analysis are not needed for portions of new weapon systems that may be adopted or adapted from a system in being. The rationale advanced may be that "we know how to train people to operate and maintain this part of the equipment." This may, of course, be true and the pace of development of the Personnel Support System may be accelerated by the use of existing data. However, unless the existing training for such equipment has been based upon task analysis it should be adopted with some reserve.

Most HumRRO training research has been effective in improving the efficiency of current courses by following procedures essentially equivalent to those described in this report. For example, Task FORECAST[2] demonstrated for an electronics maintenance MOS that experimental training, based on a "cue-response" type of task analysis and requiring less than half as much time as the standard course, produced graduates who were, for practical purposes, equal to standard graduates in proficiency. As more Army training is based upon procedures such as these, however, it would be appropriate to use existing data for subsystems that are incorporated into new weapon systems. Only the problems occurring at the interface would require new analysis.

In looking to the future, one additional area will be discussed briefly. This concerns the development of methods for the management of the central data pool so that it can quickly, accurately, and efficiently support the various products dependent upon it. It is believed that attention given to this area would produce most fruitful results.

The purpose would be to develop systematic procedures for gathering, codifying, and organizing the multitudinous bits of information resulting from task and skill analysis so that any change could be

[1]That this type of duplication could occur was demonstrated in the NIKE ZEUS effort. Phases I and II of the Task and Skill Analysis, Notes on Development Type Materiel/Training Manual, and the Maintenance Allocation Chart efforts were being pursued concurrently in different organizations of the contractor's establishment. In justification of a recommendation to cancel the detailed T&SA, Phase III, the following par. 4e is quoted from a USAOMC letter ORDXR-RME, to CG USCONARC, Subject: NIKE ZEUS Task and Skill Analysis and Training Aids Feasibility Study, 27 November 1961:

> *The detailed Task and Skill Analysis effort, if required, would be conducted concurrently with the Notes on Development Type Materiel/Training Manual effort and if used in lieu of Technical Manuals would represent a costly duplication of effort by separate organizations in the contractor organization.*

Notes on Development Type Materiel/Training Manuals are prototype technical manuals or the R&D version of what will later become technical manuals. They are produced by contractors to train their own and Army personnel who will engage in engineering tests. They are also used for key personnel training and for planning training curricula in the schools before technical and training manuals are produced.

[2]Edgar L. Shriver, *Determining Training Requirements for Electronic System Maintenance: Development and Test of a New Method of Skill and Knowledge Analysis*, Technical Report 63, Human Resources Research Office, June 1960.

readily incorporated and any desired combination of information could be quickly and efficiently retrieved. Depending upon the size and complexity of the man-weapon system and the resulting amount of data, the means of storing the information might range from a set of indexed or key-sort cards to magnetic tapes for use with automatic data processing equipment.

As illustrated in Figure 2, the contractor's Human Factors Department would be the recipient of all information on changes in weapon system equipment and procedures which would affect human activity. This unit would retrieve the original task entry from the pool, evaluate and record the effect of the change on the original analysis, and reinsert the task entry in its appropriate place in the mass of data, manually or by machine. This means of maintaining currency of the central pool of data would permit reproduction of all or specified combinations of the data for such purposes as may be required. Automatic reproduction from cards or taped storage media is possible and may well be economically practical with large and complex systems. Such reproduction could produce copy requiring only simple editing before publication for distribution.

Some of the factors to be considered in designing a coding system for selecting categories of information are fairly clear. The activities comprising the job a given individual can perform are governed by such things as time, place, equipment, and classification, such as operation, maintenance, troubleshooting, or repair. Maintenance tasks should be coded by echelon, in accordance with the maintenance concept for the system, in order to sort out those tasks appropriate for performance by the organization, by ordnance, and by depot. Coding would also be possible for selecting the information required for inclusion in operating, training, and technical manuals. It may be possible to select information from the basic data at a higher duty and task level to provide the more gross job description and personnel specifications.

The coding methodology could be developed most effectively in connection with a decision to implement procedures similar to those described in this report for a weapon system about to enter research and development. Its purpose would be to produce a generally applicable method of data handling.

Some efforts were expended in this area in connection with NIKE ZEUS but only within an individual training planning agency to satisfy its own needs.[1] Some experimentation in this area has also been done in the Air Force Systems Command.[2,3] A coding system has been developed which is apparently quite successful and which would appear to serve most, if not all, of the objectives listed above.

[1] Personal communication from ZEUS Division, Deputy for Combat Developments and Research, Air Defense School, Fort Bliss, Texas.

[2] J.E. Lease et al., *Methods for Computing Manpower Requirements for Weapon Systems Under Development*, Behavioral Sciences Laboratory, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, ASD Technical Report 61-361, August 1961, pp. 15-24.

[3] M.R. Marks, *A Data Organization Model for the Personnel Subsystem*, Behavioral Sciences Laboratory, Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio, ASD Technical Report 61-447, September 1961.

PERSONNEL CONSIDERATIONS IN IMPLEMENTATION

Implementation of the concept of a Personnel Support System development process discussed in this document cannot be accomplished solely by ordering it. Orders must, of course, be given. They cannot be carried out effectively, however, unless appropriately qualified personnel are available to take the necessary actions. Consequently, attention should be directed toward the qualifications required for key positions within the military and the means by which personnel with these qualifications may be obtained.

Key Positions in Military Agencies. A human factors position should be established in each developing agency, combat arms and technical service school, and supporting agency, if one is not currently in being. This position should have the responsibility and authority to direct and coordinate the human factors efforts as they pertain to personnel and training requirements for all weapon systems for which the agency is responsible.

These efforts include: (1) the development of basic job-task requirements data; (2) their analysis, interpretation, and collation to support the development of the particular end item for which the agency is responsible (training objectives, content, methods, devices, technical manuals, etc.); (3) the production of that end item. In addition, this position should bear the responsibility for the professional evaluation and approval of the human factors competence of bidding contractors as it pertains to the mission of the specific agency. (p. 42)

Personnel Qualification Requirements for Key Positions. The scientific and technical qualifications that personnel should have for assignment to these key positions cannot be recommended on the basis of any systematic study. No such study is known to have been made. However, it is possible to make recommendations on the basis of the qualifications of persons considered to have been successful in doing such work and in advancing the human factors state of the art. (pp. 22-24)

Most of these people have (1) had a firm grounding at the Ph.D. level in the behavioral sciences, with emphasis usually in experimental or industrial psychology; (2) some training and/or experience in engineering; (3) knowledge of military practices and procedures concerning man-weapon system development through employment by or membership in one of the departments; (4) a thorough knowledge of research leading to the current state of the art of building a complete Personnel Support System.

The above may seem to be ideal specifications and most difficult to obtain. While this is admitted, it should be noted that these qualifications are being proposed for what must be authoritative and thus critical positions if a marked degree of success is to be attained. If such personnel cannot be found within the Army in sufficient numbers, they can be employed in a civilian capacity or on a continuing consultative basis until such professional human factors competence is developed in military personnel.

Essentially equivalent specifications are suggested for the key position in the different agencies. This is done because the effectiveness of the products of each agency is dependent upon the efficient inter- and intra-functioning among all agencies in an integrated program aimed at a single common goal. Developing the routine procedures for the smooth operation of such a program and resolving the unpredictable day-to-day problems inherent in such a task justify the requirement for uniform qualifications of incumbents.

Subordinate Positions in Military Agencies. While the key positions should bear responsibility for human factors functions and products of different agencies for all weapon systems, subordinate positions should bear the responsibility for individual systems. These positions would be responsible for following over-all procedures in carrying out the functions or developing the products required by the mission of the agency. This would involve the direction and/or the conduct of necessary "precoordination," with peers of other agencies, on matters of mutual importance—that is, distribution of tasks by echelon, MOS, and so forth—to minimize final official coordination by parent agencies.

Such work may require part-time or full-time work in the Developing Agency Project Office or a prime contractor's plant. The latter would include monitoring human factors data production, analysis, interpretation, collation, test, and so forth, and timely use of information as appropriate to the parent agency mission. (pp. 40-42)

Personnel Qualification Requirements for Subordinate Positions. With appropriately qualified personnel in key positions of each agency, requirements for those in subordinate positions can be somewhat less strict. However, the requirement to work independently, in locations away from the home agency, does not provide optimum conditions for close supervision and training by the superior. It is believed, therefore, that a fundamental grounding in the behavioral sciences (M.S. level preferred), with specialization in the area appropriate to the mission of the particular agency, is the minimum professional qualification that should be considered.

Since military experience is considered extremely important in these positions, it is believed most desirable to select appropriately interested and experienced officers for special training in the pertinent human factors areas. These areas could be covered in a year of training at the graduate level in a program designed for this purpose. Graduates would be awarded the Master of Science degree in psychology. (pp. 23-24)

Additional Positions. There will, of course, be additional positions subordinate to those having responsibility for the mission of an agency for a specific weapon system. While college training in the behavioral sciences and education would be most desirable, it is believed that high school graduates of above average intelligence could be readily trained to fulfill the specific requirements of these positions.

These requirements may be relatively narrow in scope, closely aligned with the objectives of the agency. They will involve the application of procedures, directed by the superior, to data flowing from the system. In the organizational maintenance training area, for example, individuals with one to two years of satisfactory instructional experience might well learn quickly the techniques of developing training programs from task analysis data. As training analysts in equipment areas, for which their experience is relevant, learning the new techniques and their application could very likely be accomplished on the job under close supervision.

Further Considerations. The qualitative personnel requirements listed above, particularly for the key positions, are admittedly judgmental in nature. It would seem most appropriate, therefore, for the Army to enlist the aid of the Subpanel on Human Factors of the Army Scientific Advisory Panel in reviewing and delineating them in more detail. It might also be appropriate for this Panel to aid in obtaining suitably trained and experienced professional personnel for these positions.

APPENDICES

Appendix A

A STRUCTURE FOR PROVIDING HUMAN FACTORS INPUTS TO WEAPON SYSTEM DEVELOPMENT AND THE PERSONNEL SUPPORT SYSTEM END PRODUCTS DESIRED

Introduction

This appendix has been prepared to describe, in more detail than appeared appropriate for the report itself, a structural framework for making human factors inputs to weapon system development. Such a structure is necessary if the interdependent functions are to be properly coordinated and accomplished with maximum efficiency and economy by the professional personnel who are assigned responsibility for them.

In addition, certain data, and end products based upon them, are needed to support the development of the skilled human performance capability required by the weapon system. The end products are described briefly in this appendix, and some problems concerning where and by whom they should be produced are delineated.

Additional detailed information on the Personnel Support System is presented in Appendix B, which describes the PSS research and development process as it would operate during the development of a weapon system.

A Structure for Providing Human Factors Inputs

At the time a Qualitative Materiel Requirement (QMR) for the development of a new weapon system reaches the stage where supporting documents, standard Army specifications, and so forth are to be prepared for requesting proposals from contractors, a Weapon System Management Office (WSMO) will be established. It should be responsible for all human factors activities relative to the system, along with the other elements that make up such an office.

The WSMO would be a joint field activity with representatives from the developing agency, the training schools, and the user. It would integrate, coordinate, and monitor the system-oriented activities—including the Personnel Support System (PSS) activities—of the participating functional agencies during the development-production cycle.

Figure A-1 illustrates how the necessary human factors functions for a hypothetical missile system are interrelated. In this block diagram the missile, ground support, facilities, and materiel support blocks with appropriate subordinate functional blocks should be assumed on the line with the Personnel Support System. All might be shown under the QMR or a WSMO manager.

The Interdependent Human Factors Functions Comprising the Personnel Support System

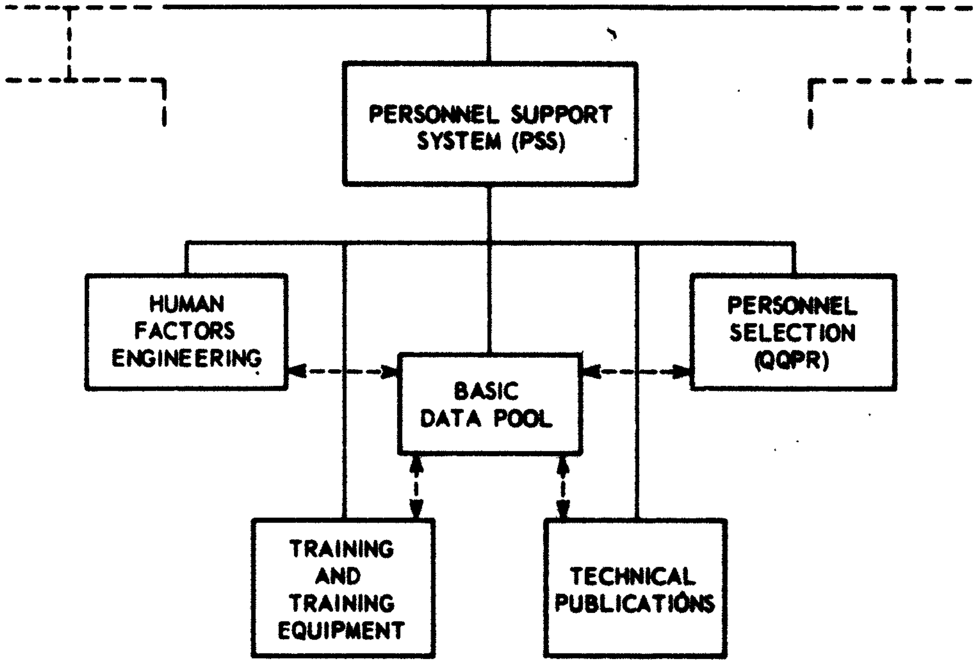

Figure A-1

In Figure A-1, the various human factors functions are shown grouped around the Basic Data Pool, to which they contribute and/or from which they draw data that are essential to the fulfillment of the various agency responsibilities. Currently responsible for these functions—and consequently required to have qualified representatives in charge, under the PSS concept—are the following:

(1) Technical Services—Human Factors Engineering; Technical Publications; part of Training and Training Equipment.
(2) The Adjutant General's Office—Personnel Selection (Qualitative and Quantitative Personnel Requirements—QQPR).
(3) User and User Schools—part of Training and Training Equipment.

The arrangement of functions should be parallel in the WSMO and the contractor's establishment. This will facilitate monitorship by the individual agency representative of the activities of his counterpart on the contractor's staff.

Personnel Support System End Products[1]

Army and/or Contractor Preparation of End Products

The extent to which it may be beneficial and economical for the Army to have contractors produce PSS end products depends upon several variables, among which are:

(1) The human factors professional competence available on the contractor's staff as compared to that in the Army agencies involved.

(2) The nature of the end product.

(3) The willingness of the Army to pursue the concept of conducting the PSS research and development process in one place, in view of the administrative problems involved (see pp. 37-40).

At a minimum, the activities of contractor human factors personnel will consist of the production of data basic to the end products of the Army agencies. The monitor and his staff would then use these data to prepare the end product. For example, contractor-produced task and skill analysis data might be used by TAGO personnel to prepare a Qualitative and Quantitative Personnel Requirements Report. On the other hand, in addition to producing the basic data the contractor might produce the end product, the QQPRR, under monitorship of a TAGO representative.

On two functional areas in particular—personnel selection (QQPR) and training—there is need for a definition of the limits of efficient contribution to the end products by the contractor's staff. An operational test of the concept, as recommended in this report, will produce evidence on which to make more objective judgments than can be made at this time.

End Products in PSS Non-Training Functional Areas

Training Equipment and Technical Publications

The "hardware" components of the PSS—the training equipment and the technical publications—currently are developed essentially to their final configuration by contractors under Army monitorship.

Personnel Selection

It would seem advantageous to have contractors prepare a Qualitative and Quantitative Personnel Requirements Report. It should be used upon the task and skill analysis data in the basic data pool and

[1]The term "end product" is used in a general sense throughout this section. It includes any PSS element that must be developed to support other products or processes that ultimately lead to proficient performance on the operational system. Thus task and skill analyses, if formally published and distributed, could be considered an end product even though the data are basic to other end products (e.g., QQPR, technical manuals, training programs, training equipment).

the operations and maintenance plans. It should provide job descriptions and recommendations of the numbers and kinds of Army personnel required to operate, maintain, and control the system. With the help of the Army Personnel Selection Monitor, these jobs should be identified by MOS. Monitor personnel should supply the estimates of job proficiency levels.

It does not appear that contractor personnel should supply estimates of aptitude requirements such as minimum Armed Forces Qualification Test (AFQT) scores. It would seem that this function can be better handled by the professional staff in TAGO.

Training End Products and PSS Considerations

Within the area of training, the ultimate end product is, of course, the trained man. Short of this, however, there are many items and processes with which the contractor must be concerned, if he is to produce a maximally operable and maintainable man-weapon system. Some but not necessarily all of these, beginning with the most basic, are discussed below.

(1) Task and skill analysis data. These data result from an analysis of the interrelationships of functions performed by system personnel and system hardware. They are maintained in the basic data pool and are drawn upon by human factors specialists to prepare other Personnel Support System elements.

A given task (e.g., a procedure), as it will be performed on an operational system and consequently be a basis for training, is the product of an evolutionary process. Initial analysis may have suggested equipment design change that reduced the complexity of the task. Further analysis may have suggested an aid, checklist, or other means of storing readily available information, which further reduced the knowledge requirement. In its final form, then, the task a trainee must learn is that which results from this process, including incorporation of the perfected aid.

Insofar as all the products dependent upon these basic data may be developed where they are generated, by either contractor or Army personnel, a formal task and skill analysis publication would not have to be distributed.

(2) Job and manpower requirements information. Supplementing the QQPRR already discussed, the detailed task and skills data must be grouped into jobs to determine what individuals must be able to do when finally assigned to the system in the field. The numbers of personnel required may be determined from the QQPRR, but the job descriptions sufficient for that document do not provide enough information for developing training programs.

(3) Training objectives. While the preceding step reveals what must take place on the job, it does not prescribe that all included

therein must be a part of the formal training programs. Growing out of a study of the operational and maintenance plans, environments, facilities, etc., as well as the nature of the tasks, skills, and knowledge that must be acquired, will be a selection of the portions of the training that are best suited for formal school, unit, or on-the-job training programs. The training objectives must be stated in terms of specific descriptions, concerning each task or group of related tasks, of the overt behavior expected of a trainee at the conclusion of training.

The fact that some individual trainees or groups of trainees may be expected to already have certain of the required knowledge, skills, and abilities should not preclude the spelling out of a complete list of objectives and their assignment to the different kinds of training programs. This procedure will prevent possible omission of important items, and will permit modifications when pretest or other measurement indicates that the skills are present in groups of trainees.

(4) Training content. Training content must be selected and designed specifically to achieve the training objectives quickly and efficiently. Only the content that can be demonstrated as relevant to achieving the behaviors described in the objectives should be included. Nice-to-know, theoretical, and advanced information for more technical jobs may be available for the motivated trainee. Inclusion of such information in the training program, however, not only might be irrelevant and wasteful, but might actually interfere with the most efficient attainment of the specific training objectives.

Training content may be presented in the form of lesson plans. It should, in any event, be designed for presentation by specified training methods and make use of training equipment designed in coordination with the requirements.

(5) Training methods exploiting learning principles. Selection of methods to be used in training is a step not readily separable from selection of training content. Suffice it to say that as content is developed for any given method, careful attention should be given to assure that the presentation (a) is meaningful in terms of the future job already thoroughly described, or is associated with already learned materials; (b) causes the trainee to be active in the learning process; (c) provides him with feedback as to the accuracy of his attainment; (d) avoids interference or conflict throughout the course or program of courses and, if possible, with other firmly entrenched learning or habit; and (e) makes provision for individual differences in abilities, experience, and motivation.

The relationship of training method to training equipment should not be overlooked. There are occasions in which use of job, task, or part-task trainers is the most effective method of implanting skills, knowledge, and abilities. Requiring the systematic buildup of complete training programs in this manner during system development may well provide, at this training content-method selection stage, insights as to training equipment requirements that were not possible at the earlier task and skill analysis stage.

(6) Proficiency tests to measure attainment of objectives. The final PSS end product, short of the trained man himself, is the package of job proficiency tests based upon the training objectives to measure their attainment. If the training objectives properly represent the tasks that comprise the job, a job performance test based upon them should adequately represent the predicted job.

These tests must be objectively scorable. The standard of proficiency may have to be set somewhat short of that desired after job experience. Job proficiency test problems and scoring procedures must have certain characteristics:

(a) They should be stated in clear, unambiguous terms so that the student knows exactly what task he is to perform, and so that the testing personnel know exactly how to score the various kinds of performance.

(b) The test should permit diagnosis. For example, where long and complex performance is required of the student, forms used by the examiner to assist in scoring should be so designed that they will identify just where the student goes wrong.

(c) Tests should be so designed that failure to perform significant items correctly will not be hidden by successful performance of insignificant items. This can occur when all items are scored on a percentage basis. Consequently, significant items should be identified, and scored on a pass-fail basis.

(7) The trained man. As stated earlier, the trained man is the PSS final end product in the training area. Contractors have trained Army personnel in the past but these individuals have, however, been much more highly qualified than the mass of trainees the Army must train in its schools. Because of their unusual level of ability, training for key personnel has probably never been as formally structured and administered as the training described in the preceding steps. Some training of key personnel has been described as being so informal as to consist of reading the technical literature, "looking over the shoulders" of contractor technicians, and viewing and working with hardware prototypes. While this of course has had value, it can hardly be judged to be comparable with the systematic procedures described here as a means of obtaining training data and structuring school training programs.

> If contractors were required to follow such systematic procedures in building training programs for key personnel, these program materials would appear to be a most desirable PSS product. The cost of their development should be included in the cost of key personnel training. If the Army pays for such training it is entitled to prescribe the manner in which the program is developed. The above procedures have built-in quality controls that will go far in assuring that the end product, the trained man, is of the quality that the Army desires.

The final step in training program development remains for consideration. If the program prepared by the contractor has been designed for training highly qualified, experienced key personnel, its objectives, content, and tests will have to be reduced in complexity to a level appropriate for the training of less well qualified trainees. The choices to be made as to where, and by whom, this work should be done may be stated as follows:

> First, should the training program be developed at the prime contractor's plant or at Army schools? Then, if it is decided that the program will be developed at the contractor's plant, should the work be done by contractor or by Army human factors specialists?

The three major alternatives for training program development therefore appear to be (1) at the prime contractor's plant by contractor human factors personnel, (2) at the prime contractor's plant by Army human factors personnel, or (3) at Army schools by Army human factors personnel. Various aspects of the advantages and problems involved are discussed below.

Should the work be done in the contractor's plant or in Army schools? Accomplishing the work at the place where the basic data are generated has a number of advantages:

(1) Work can begin at an earlier stage. As soon as task and skill analysis data begin to accumulate, they can be studied with regard to the requirements they impose for training. This examination, coordinated with consideration of aids and training equipment, may well provide valuable feedback for the human factors engineers on the design team. Thus training problems are introduced for consideration while the design is still fluid, much more readily than would be the case when the systematic program development takes place at a school remote from the system equipment development following production and publication of, by this time, relatively frozen data.

(2) Tasks are less subject to change. When tasks are initially analyzed and considered from all points of view, including training, the version of the task that finally emerges is much less likely to change later in a manner that will affect training objectives and content.

(3) Quick response can be made when tasks do change. Administrative procedures requiring that task data be coordinated with training materials will ensure that the changes are evaluated for significance for training. Any required modification can then be incorporated in materials already prepared.

(4) Manpower requirements for training program development can be predicted. Weapon system hardware is developed according to a well-defined and quite firm schedule with associated rewards and penalties. Requirements for manpower for work on the training program can begin at quite a low level. As the volume of data increases with the progress in hardware development, more manpower can be assigned. The relationship between the two curves (manpower needs and hardware development) can be measured. When this relationship can be determined in the individual contractor plant, the rise and fall of manpower needs for work on the training program can be quite firmly predicted well in advance.

(5) No publication and distribution of basic data is required. This point was mentioned in Par. (1) but requires some further elaboration. Publication and distribution of task and skill analysis data requires a sizable and expensive manpower effort. It involves explanation, organization by echelon, and publication processing, generally at some milestone well along in system development. Later issues must be published to cover changes that occur.

On the other side of the coin, commanders of Army training establishments have a well-recognized concern for the quality of their training programs—indicated, for example, by requirements for frequent briefings by their staffs during program development. The extent to which they may be willing to delegate to a training monitor, however professionally qualified, responsibility in this important area at a distant location is an unknown. They may tend to prefer having the training programs developed by their own people at their own posts. Such feelings might be counterbalanced by the presence on the commander's staff of a broadly trained and experienced human factors professional—one of the key positions described in the report (see p. 45). As stated earlier, only an operational test of the alternatives can yield anything better than opinion at this time.

Should the work be done by contractor or Army personnel, if done in the contractor's plant? Assuming total training program development at the contractor's plant, the question of preparation by contractor vs. Army personnel needs examination. The main advantages of contracting for complete training programs may be summarized as follows:

(1) The most obvious result would be the reduction in numbers of Army personnel needed on the training monitor's staff. It is possible that, once complete T&SA data are being produced and converted into satisfactory training materials, only periodic monitoring would be required.

(2) The administrative problems associated with having a varying number of qualified Army military or civilian personnel working away from their permanent duty stations would be minimized.

(3) Because of changing military duty assignments and varying lengths of tours, particularly among enlisted men, the Army might find it more difficult than would a contractor to maintain a single group of training specialists from the beginning throughout the period of system and training program development. Continuity would seem,

clearly, to be a desirable factor in the efficient production of any given training program.

(4) Military experience and its significant influence upon the design of operator and maintenance training could retain its emphasis under the contractual arrangement. Retired Army personnel with this experience are frequently found on defense contractors' staffs. In addition, officer monitors are expected to review contractor output from this point of view. Officers selected for specialized training in human factors would be expected to have a predetermined amount of experience in the branch for which the system is being developed.

(5) A more integrated attack upon the total training program can be made by taking full advantage of the work done for the key personnel training. This would be true whether the work was done by contractor or Army personnel, but less duplication is probable if one integrated group does the whole job.

Army personnel working in the schools. The third alternative is the development in the schools of training programs based upon data supplied by the contractor after approval by the WSMO. Objections to this, reflected in the preceding discussion, include a reduced ability to conduct the operation integrally with the production of data, delay while waiting for formal publication of data, and the expense attendant thereto.

These objections can be overcome, to some extent, by dispensing with the formal publication of task and skill analysis and other pertinent data at some system development milestone. Instead, task data approved by the WSMO Training Monitor may be sent to the appropriate schools on a week-to-week basis as working papers. In other words, at the same relative time the monitor would release data for the beginning of training program preparation at the place of their origin, he would send them to the school. This would permit gradual manpower buildup as the volume of data increased. In case of an interrupted flow, it would allow the skilled training analysts to be used effectively on other programs in the school. Such an interruption, if these people were working in the contractor's plant, might leave no alternative but idleness. And, of course, the administrative problems involved in maintaining larger numbers of service personnel away from their permanent stations would be eliminated.

Appendix B

THE PERSONNEL SUPPORT SYSTEM RESEARCH AND DEVELOPMENT PROCESS IN OPERATION

Throughout this appendix appropriate materials have been drawn or adapted from the following document:

> Hq, Air Force Systems Command, Handbook of Instructions for Aerospace Personnel Subsystem Designers, AFSC Manual 80-3, ASD (ASNXH), Wright-Patterson AFB, Ohio, 1 July 1961.

Personnel concerned with implementation of recommendations in the basic report or further expansion of the discussions contained in this appendix should consult this document.

Introduction

Detailed information on how the Personnel Support System Research and Development Process (as it pertains to training) should operate is provided in this appendix, as an aid to achievement of the objectives stated in this report. Toward this end, illustrative actions to be taken by key civilian or military human factors specialists will be traced, from the establishment of a Qualitative Materiel Development Objective (QMDO) through all stages of development, production, and operational use of a hypothetical weapon system.

The major milestones in the chronological development of such a system are shown in Figure B-1. The same order will be followed in this appendix in discussing human factors inputs concerning the major milestones. It should be noted, however, that the PSS activities occurring during the design and development stages are interdependent and to a large extent progress concurrently rather than chronologically. Also, while the man processes and products are shown as separate from machine development, this does not mean that they are developed separately. Rather, as indicated by the arrows between them, there should be a constant interchange of data, coordination, and action to seek optimum man-machine solutions.

In those cases where the design and development of weapon systems are accomplished by contract with industry, the Army human factors specialists will be concerned mainly with providing the specifications for the various PSS products the Army needs, interpreting when necessary, and monitoring their production. When the Army elects to design and develop a total system itself, as in the case of the JUPITER, these human factors specialists would develop the personnel support system products themselves. Their functions would change, at the time a production contract was let to industry, to one of monitoring to see that changes occurring in the production process would be reflected in the final products. In the following discussion it will be assumed that the system is being developed under contract with industry.

The Qualitative Materiel Development Objectives (QMDO)

Characteristics of the QMDO Stage

The Qualitative Materiel Development Objective is a statement, approved by the Department of the Army, of a military need for development of new materiel, the feasibility of which cannot be determined sufficiently to permit the establishment of a Qualitative Materiel Requirement (QMR). It, therefore, is broadly stated as a goal toward which research efforts should be directed.[1]

[1] AR 705-5, 21 December 1959, sect. III, par. 9.

Chronological Development of a Weapon System

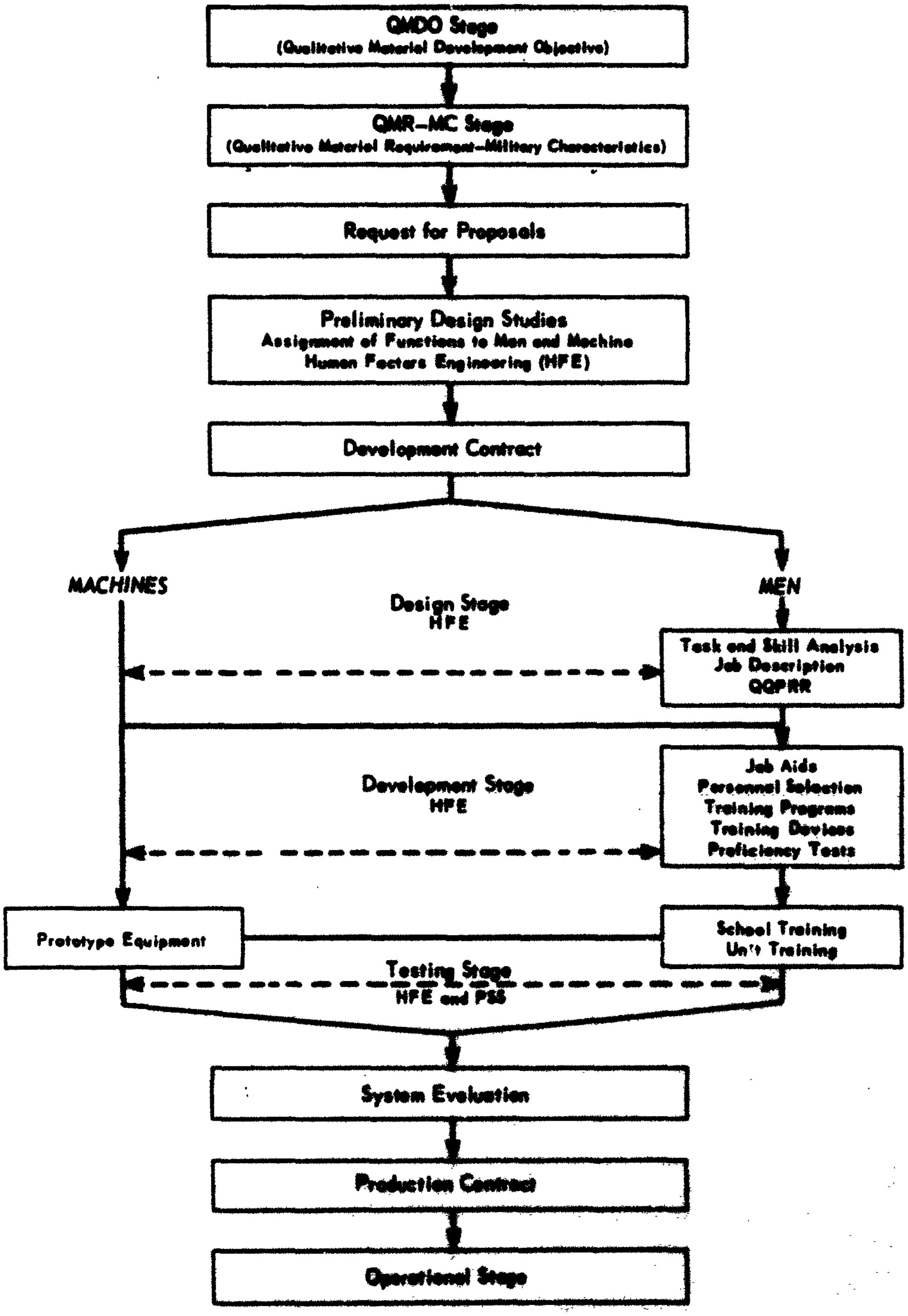

Figure B-1

A QMDO may originate from a need to counter or surpass the known capability of our own or potential enemy weapons. The advent of a successful ICBM, for example, caused the immediate recognition of a need for defense against it.

During the QMDO stage, the state of the art in all pertinent areas is searched to determine whether, for example, the technology that could produce the threat could produce a defense. A variety of theories or hypothetical solutions may be advanced. Some of these, separately or in combination, may be known to be feasible and capable of accomplishment within scientific, technical, production, time, personnel, and budgetary means. Others may require an extension of current capability. For example, a missile may have to go farther, higher, and faster and kill a smaller target than ever before, with greater reliability. Yet, even with this greater capability, it must be simple to operate and maintain by people whose psychological and physiological limits have not advanced in any measure comparable with the limits constantly being extended by the technology. In addition, it must be practicable to train the bulk of these people from a position of relative ignorance, in a matter of weeks, so that they can perform their jobs proficiently for a significant portion of their single tour in the Army.

Combat development study projects are directed toward a determination of operational concepts and techniques, new organizations, or qualitative materiel requirements for the Army. The Chief of Research and Development (CRD) maintains a continuing emphasis, in basic and applied research and component development, to provide (1) the requisite state of the art for support of systems developments and (2) a sound basis for determining, before initiation of projects, the technical feasibility, time required, and cost of the project.

Human Factors Inputs at the QMDO Stage

Since the QMDO stage is concerned only with system functions, requirements, and design parameters, without assignment to man or machine components, human factors specialists can make no significant contributions for a specific weapon system at the QMDO stage. The only human factors research and developmental work that would be appropriate to a given objective at this stage would be basic in nature, contributing to our knowledge of man's capabilities. Also of value during this period is a continuing compilation of the characteristics of personnel coming into the Army, which will provide the best estimate of the men who will be available to the Army in the future, at least during peacetime. This type of research, nonspecific to a given system, is the responsibility of CRD. It provides data which can be applied, in subsequent stages of system development, by the human factors specialists assigned to specific systems or projects, those with whom this report is concerned.

Army Regulations 11-25[1] and 705-5 direct that qualitative and quantitative personnel implications and feasibility of training individuals and

[1]Department of the Army, *Army Programs: Reduction of Lead Time*, Army Regulations No. 11-25, 27 September 1961, sect. II.

units within a specified time period will be determined as a part of the determination of the total feasibility of each major research and development systems requirement. It is difficult to see how any of these things can be done with any degree of validity at a time preceding the issuance of a QMR. It is worth noting that the QMR itself specifies[1] that "The statement should avoid dictation of the actual technical approach, but must describe what the equipment should do and specify both upper and lower performance limits." Equipment can do nothing in isolation from human input (control, operation, maintenance). Human input appears to be inseparable from technical approach. Unless some technical approach is assumed, it would seem impossible to estimate in any specific, reliable way how many of what kind of people would be required to man a system, or how long it would take to train them to do so.

It is possible to stipulate numbers and characteristics of personnel as constraints upon design (e.g., desired crew size). To do more than this would be to duplicate what must be done at a later stage following issuance of a QMR and Requests for Proposals. At this time, one or more contractors make feasibility studies and propose their solutions for development of a system to satisfy the approved QMR. Under present regulations, prior to issuing an approved QMR, it seems pertinent to ask how the feasibility of training individuals and units within a specified time can be determined when the functions man will fulfill in the man-machine combination have not been specified. Until it is known what tasks a man must perform, it appears unrealistic to expect dependable estimates regarding what training he will require or how long it will take.

The Army may, however, elect to design a system that includes the analysis of functions and their assignment to man and/or machine components in what is construed to be a systematic feasibility study. In this case, two modifications of present procedures would seem to be appropriate:

(1) If the feasibility investigation is successful, the statements in the QMR should dictate the technical approach.

(2) Human factors specialists should be involved. The extent to which they should or might be involved will be described in the sections to follow, which will trace the course of systematic development of a PSS concurrently with materiel development.

The Qualitative Materiel Requirement

Function of the QMR

"The QMR serves to state the materiel needs of the user in terms of fundamental characteristics and to relate materiel to the operational and organizational context in which it will be used. QMR's are stated

[1] Sect. IV, par. 7 of Incl. 2, Hq, CONARC Staff Memo No. 2, 1 February 1962.

at the earliest time after the need is recognized and feasibility of development has been determined."[1] "Military characteristics (MC) will be included in the statement of the QMR, thus eliminating the MC as a separate document except for those items requiring approval of the Atomic Energy Commission."[2] An approved QMDO may evolve into one or more QMR's.

Human Factors Inputs at the QMR-MC Stage

For the same reasons given for the QMDO, there can be no human factors inputs specific to a given weapon system in the preparation of a QMR. It is possible, however, to make non-system specific statements which would be more meaningful than those contained in current MC's, regarding the constraints upon design created by the type of personnel available to the Army for operation and maintenance. For example, "men who will be trained to maintain this system must be able to learn the job in X weeks of training when the range of aptitude of trainees is X to X as measured by the Armed Forces Qualification Test (AFQT)." Providing ever more accurate data and improved descriptions of the characteristics of people falling within this range is the continuing responsibility of human factors research agencies under the CRD. Such information would increase the ability of design teams to make use of human factors data in systems they propose.

There are three activities of a general nature that human factors specialists should accomplish with respect to a QMR-MC:

(1) They should review the QMR-MC to assure that all statements that have connotations for personnel requirements are as complete as the state of their art will permit. For example, on a requirement that a system be capable of remaining on the air 23 out of 24 hours, the maintenance aspects can be made more meaningful by stipulating the constraints. The limitations that are prescribed—such as on availability of spares, or system redundancy—have significance for design, with regard to ease of maintenance and the consequent length and complexity of training.

(2) They should review the QMR-MC to assure that no requirements are included that cannot be justified at this stage. For example, MC's for MAULER[3] and FABMDS[4] are quite specific with respect to requirements for certain training devices. These requirements read very much alike and require very similar devices. This suggests that, to comply with the AR direction that requirements for training devices be included in MC's, and for lack of inspiration or knowledge of the most appropriate statements to be made at this early stage, the form sometimes is completed by indicating the same types of requirements

[1] AR 705-5, 21 December 1959.

[2] AR 11-25, 27 September 1961.

[3] See *Training Aid Requirements for MAULER Forward Area Guided Missile System* (U), Appendix III to OTCM 37041, 27 January 1962 (SECRET).

[4] See Annex to *USCONARC-Approved Military Characteristics for the Field Army Ballistic Missile Defense System* (U), Proj. Nr. GM-3059, 26 August 1960 (SECRET).

that were approved for the last similar QMR.[1] When these statements subsequently are strictly interpreted as requirements for specific training devices, more efficient solutions to the problem are not found because they are not sought.

In addition, at least for FABMDS for which the MC's were approved before contractor feasibility studies were made, the MC's appear to anticipate what the eventual system will be, before its functions have been assigned to man or machine. As stated in the main body of this report (see pp. 33-34), there may be justification for some general, over-all trainers based on experience. However, human factors training specialists would avoid stating that models, cutaways, mockups, etc. are required until such time as an analysis of the specific tasks and training requirements indicated that such devices would be essential for efficient acquisition of the needed knowledge and skills. A specific statement in approved MC's that these devices are required could be cited at a later date as justification for purchase. Actually, pertinent research, with which proficient human factors specialists should keep current, may suggest more effective or economical means of resolving the training problem.

(3) While the QMR is being staffed,[2] and as a part of the preparation by the developing agency of the technical characteristics (TC) based on the QMR, human factors specialists should prepare specifications, exhibits, and similar materials. These would spell out for contractors, interested in making proposals, the requirements that would be placed upon them to produce basic HF data and, where appropriate, PSS products dependent upon them.

These requirements would include but not be limited to considerations in the R&D directive on human factors engineering (HFE) in development contracts.[3] In addition, they would specify giving human factors attention at the same professional quality level to personnel selection—qualitative and quantitative personnel requirements (QQPR)—and to training programs of instruction (POI's), aids, devices, technical manuals, and so forth. No official document, similar to R&D Directive No. 70-21 on human engineering, is known currently to specifically direct this additional kind of professional human factors attention. (See Appendix C for proposed R&D Directive which combines this requirement with HFE.)

To supply this human factors documentation in addition to that normally furnished in response to Army Requests for Proposals, a contractor should give both direct and indirect evidence of the following kinds in support of his capability to fulfill the requirements:

(a) A statement of the educational qualifications and experience of the professional personnel on the human

[1]This practice may be followed to solve budgetary or other administrative problems but it may raise other problems with respect to training equipment, as will be noted. A more direct solution to the budget problem for training equipment should be sought.

[2]AR 11-25, 27 September 1961, sect. II, par. 7g.

[3]See R&D Directive No. 70-21, 8 December 1961.

factors staff, including length of service with the contractor, those assigned to work on this proposal, and those who would be assigned to this contract if won.

(b) Information for use by the Army in evaluating the proposal with respect to the anticipated human factors engineering effort for the system, as a part of their design selection criteria. This information will include:

(1) A summary of the results of the HFE effort expended during the system study phase.

(2) A proposed plan for incorporating HFE principles into the design of the developmental model.

(3) A description of any research specific to the system which would be required to resolve HFE problems.

(c) A proposed method of determining the personnel and training requirements imposed by the operational use of the system. This information would be used primarily to judge the bidder's personnel support system concept and his potential ability to develop it on a systems engineering basis along with the hardware and logistic support system. It will include:

(1) Descriptions of the anticipated method of operation, maintenance, and control of the system; the ground equipment, including maintenance and handling equipment; facilities and environmental conditions; special tools and test equipment. On the basis of the foregoing, a statement of the numbers and types of personnel required to accomplish the system's mission.

(2) Predictions and recommended solutions for unusual personnel or training problems inherent in the proposed design or operation of the system.

(d) A forecast of the types of training equipment that will be needed to support individual, unit, and on-the-job training programs. Data requirements include:

(1) Description of the methods planned for identifying the need for and characteristics of training equipment, special training problems anticipated because of the system's design, and any unique facilities required.

(2) Identification of categories (simulators, devices, aids, accessories, etc.) of training equipment required. Indication of the training functions to be accomplished and a statement concerning the assumptions, concepts, and information upon which the recommendations are based.

(3) Tentative identification of portions of operational equipment that will efficiently, economically, and safely satisfy requirements for training equipment.

(4) Evaluation of any technical development or research required to satisfy the expected training equipment requirements.

Human Factors Inputs At the Proposal and Preliminary Design Study Stages

After the QMR has been approved and human factors specialists have developed specifications or adapted existing specifications for a given weapon system, subsequent actions consist of inviting proposals from industry and evaluating them. In some instances the proposals of several contractors are accepted for further preliminary design or feasibility studies. These consist of continued development of the proposed configurations, or alternatives within them, for a period of a few months until, upon evaluation, a single system can be selected for development.

The human factors activities during proposal and preliminary design study evaluation are fundamentally the same, except for intensification in the case of the latter, and will be covered together. When contractors have had an opportunity to submit their proposals (or study results), a team of Army technical personnel, including human factors specialists, evaluates their relative capability. This is done in terms of their understanding of the problem, soundness of approach, special technical factors, and compliance with the requirements of the requesting documents.

The human factors specialists, who must work in close coordination with the other technical specialists as a team, evaluate the proposals with regard to human factors engineering, personnel, training, training equipment, and technical data. The bidder's responses to items such as those outlined on page 8 provide a basis for evaluation.

On the basis of the team's recommendations and cost considerations, a contractor is selected and the system enters the development stage.

Human Factors Inputs During Development and Production Stages

Throughout the development and production stages, various personnel support system specialists (e.g., human factors engineering, personnel, training, training equipment, and technical data specialists) of the appropriate Army agencies monitor the contractors' personnel support system efforts through the Weapon System Management Office. The data programs described in this section are designed to assist these monitors in managing and controlling the various aspects of PSS development to ensure compatibility of the end products (training courses, training equipment, and technical publications) which are used to develop qualified personnel to operate, control, and maintain the system.

The contractor must furnish to the Army during the development stage sufficient information to enable the WSMO monitors to determine that the system will be suitable for operational employment and that the system design characteristics are within the performance capabilities of Army personnel who will operate, maintain, and control the system. These development data represent an extension of the design selection data submitted with the contractor's initial proposal and provide for continuous updating of system basic data.

Figure B-2 illustrates how personnel support system requirements are organized within the over-all development of the system, identifies the basic human factors data used in developing PSS elements, and shows the flow of PSS functions during the development effort. (The diagram does not detail non-PSS activities which are parallel and concurrent during system development.) In the PSS flow chart portion of the illustration, PSS development activities are grouped in five major areas: human factors engineering, personnel, training, training equipment, and technical data.

Human Factors Engineering Design Development Data

Army specifications should be developed, if they do not exist currently, to direct contractors to furnish information to the WSMO for use in monitoring and evaluating the human factors engineering effort during the development of the system.

A first requirement should be for a program report to be submitted within a specified period following contract initiation. This report should detail the proposed human factors engineering program, including the schedule and methods for collecting, analyzing, and applying HFE data. Subsequent periodic progress reports should reflect development progress, design modifications, and changes in system requirements.

Data of the following kinds should be included in these reports (see flow chart blocks under Human Factors Engineering, Figure B-2):

Personnel functions and procedures. Detailed information should be submitted to show that the functions allocated to man-machine combinations will make optimum use of man and machine capabilities, and that manned functions are compatible with system criteria. It should include continuing time-based analyses, specific to the system, of normal and emergency operations relevant to accomplishing the mission and critical maintenance activities under both normal and emergency operating conditions. Whenever any modification affecting operator response is considered, the effects on over-all system performance must be clarified. Analyses of emergency operations should include consideration of unit performance as it might be affected by various unit member disabilities, equipment malfunctions, or lack of system articulation in mission performance which might result from personnel problems, malfunctions, communication or delivery dislocations, inclement weather conditions, etc.

Organization of the Personnel Support System

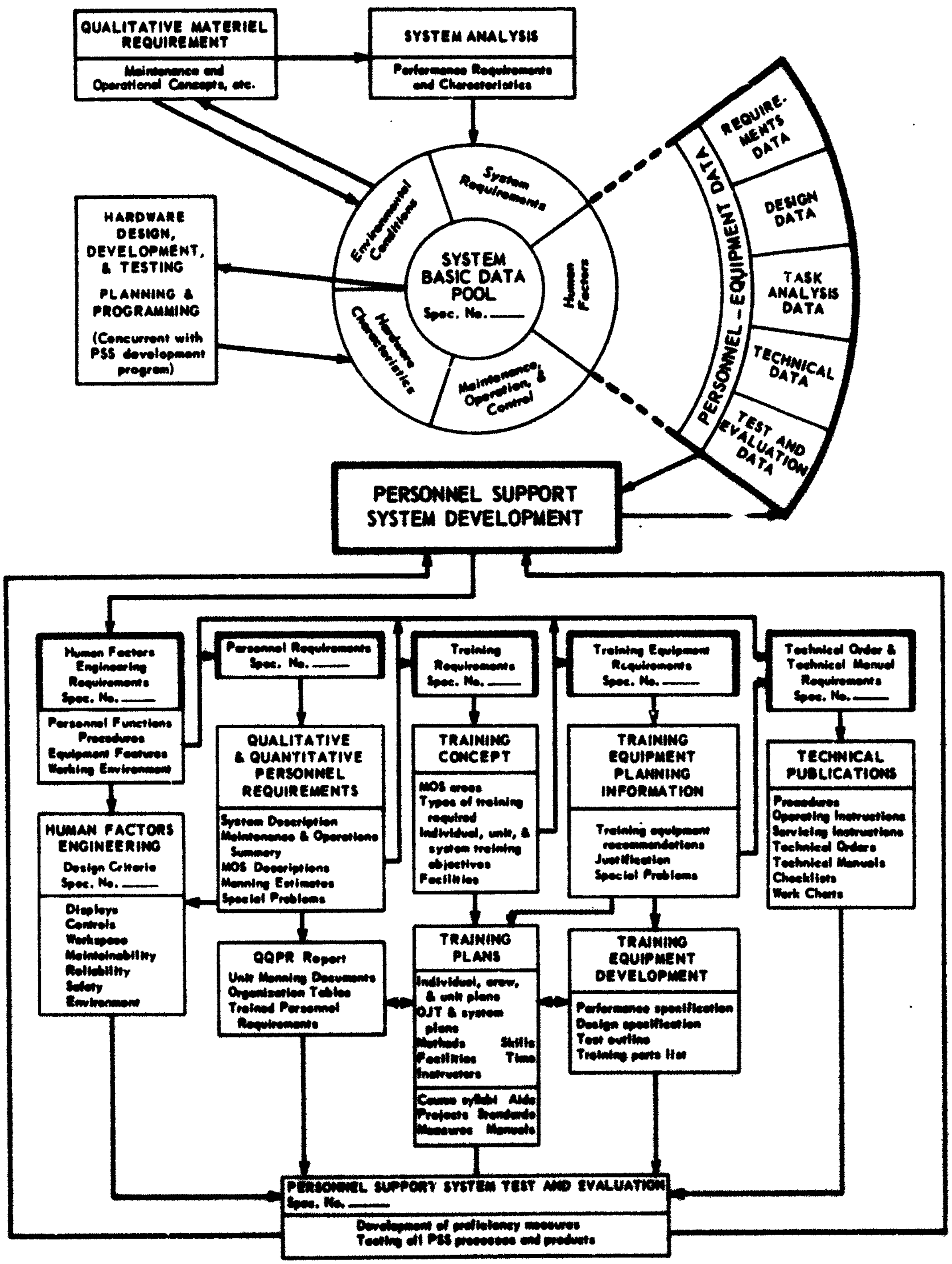

Figure B-2

Equipment. These data should include scale drawings that specify workspace dimensions, control-display layout, and functional areas; control-display relationships; operating sequence and frequency; accessibility of components; and lighting, labeling, coloring, coding, etc. Drawings should be accompanied by a clear rationale of the layout, based on the analyses underlying the design decisions.

Working environment. These data should cover the performance capability of personnel when subjected to relevant combinations of working environment variables, such as vibration, noise, isolation, restrictive equipment, etc.

Research. A report should be submitted on the results of any Army-approved research that the contractor has performed on human factors engineering problems specific to the system under development.

Personnel Developmental Data

Specifications (or work statements specifying what the contractor is to do) should require that, early in the development period, the contractor will furnish detailed and definitive information that will enable the Army to determine the personnel required to operate, maintain, and control the system. Such data (combined in a Qualitative and Quantitative Personnel Requirements Report) should cover all positions directly associated with the operation and control of the system and those associated with all echelons of its maintenance. On the basis of design, environment, task, and other data, the kinds (Army Military Occupational Specialties—MOS's) and quantities of Army personnel required by the system are specified. The information serves three basic purposes:

(1) It permits systematic identification of Army MOS's.
(2) It fosters the orderly development of organizational tables and unit manning documents.
(3) It provides a valid basis for developing training plans.

The QQPR effort may also contribute to the refinement of operation and maintenance plans and concepts. Administrative controls should be established to avoid duplicating the collection and analysis of information which is common to several programs.

The draft and final forms of the QQPR report should contain the following (see flow chart blocks under Personnel Requirements, Figure B-2):

System description. This should be a concise functional description of the military purpose and operational characteristics of the system—stating typical operational cycles, discussing the maintenance and operational concepts involved, and identifying new equipment.

Maintenance and operations summary. This should be a narrative and pictorial summary of the work flow for system operation, test, and maintenance activities. Illustrative material may include work flow diagrams, task tables, and operator performance analysis diagrams. Team performance requirements should be specified, and the amount of time required to perform job operations should be estimated.

MOS descriptions. Descriptions should be submitted for all jobs required in the operation, maintenance, and control of the system, identified by existing or recommended new Army Military Occupational Specialties (MOS's). Each job description should include:

(1) A statement of the general features of the job.
(2) A list of duties and tasks in sufficient detail to provide a clear picture of the work responsibilities.
(3) Information about special tools and test equipment used.
(4) An estimate of the time, location, and frequency of performance of each duty.
(5) Sufficient information on probable task performance errors, special equipment-handling requirements, unusual control manipulations or display interpretations, special hazards, or procedures, to enable the Army to determine the task proficiency level required for each task within the job.

Preliminary manning estimates. Estimates should be submitted of the number of suitably trained personnel (identified by existing or recommended MOS's) that will be needed to perform duties of each MOS. Manning estimates tables should be supplemented by organizational diagrams to illustrate the over-all functional organization required for the system, including the composition of major units and teams.

Special problem areas. Any unusual personnel requirements or task performance hazards needing special emphasis should be stated, and recommendations should be made for solving these problems. Suggestions should be oriented toward individual aptitudes required, special training that may be necessary, or equipment and control modifications which might alleviate the problem.

Personnel Planning Actions

Qualitative and Quantitative Personnel Requirements Reports should be prepared either by the system contractor or by WSMO personnel from contractor-furnished equipment and task data. As soon as a draft QQPRR is available it should be reviewed by the QQPRR Project Officer for the system, coordinated with other WSMO representatives, amended as necessary, and submitted to the appropriate higher headquarters for review. A personnel planning conference may then be held with representatives of the participating functional agencies, to resolve differences, direct changes, or approve for publication the information contained in the draft report.

QQPRR's often require updating by means of change reports as more detailed system basic data and personnel equipment data become available for analysis of job requirements. Such change reports should be processed in the same manner as the draft QQPR report.

Upon publication of the approved report, it becomes an official document which serves as a guide for personnel classification and manpower planning. When the using agency has presented its proposed unit manning document for the system, a personnel guidance letter which details the total system manpower requirements and Army MOS's necessary for the particular system may be issued.

Training Developmental Data

Work statements for the contractor should recognize the need for identifying detailed training requirements upon which a training concept can be based and training plans formulated (see flow chart blocks under Training Requirements, Figure B-2). A training analysis of the data prepared for a QQPRR, as well as task and skill analysis data from the basic pool, is used to determine various factors of importance in planning training, such as:

Requirements for training on specific skills and knowledges. Tasks requiring training emphasis should be identified, and the types of skills required for task performance should be evaluated in terms of possible training difficulties. Any critical task performance requirements must be identified and evaluated.

Recommended training methods. (See pp. 54-56, Appendix A.) The training objectives and the methods proposed for achieving them by developing the required skills and knowledges should be described, along with tentative standards indicating the degree of proficiency to be achieved. The kinds of training should also be indicated, such as individual classroom training, operational training as a unit or crew member, and OJT. Consideration should also be given to the feasibility or need for planning comprehensive system training.

Training time requirements. Estimates should be made of the time required to complete training on specific tasks or groups of related tasks, probable length of the course, and the distribution of training time between skill and knowledge acquisition and proficiency measurement.

Instructor and facility requirements. Instructor and training facility requirements related to the estimated system needs for trained personnel should be tentatively established.

Information such as that described above will establish the training requirements of the system and will contribute to the identification of training equipment requirements and characteristics.

Training Equipment Developmental Data

A variety of equipment may be required to support the factory, individual skills integrated team, maintenance, and transition training programs, as well as the personnel proficiency measurement program. The identification of all training equipment required in support of the system, and the preparation of functional specifications of these items, must occur early in the development stage in order to meet lead-time requirements for development, fabrication, checkout, and installation.

Once the personnel training needs have been established for the various types of training, the training equipment required in support of these programs must be specified. Training requirements should be analyzed to develop functional descriptions of all training equipment proposed; the equipment requirements should be justified in terms of the training concept, learning requirements, and the specific skills to be acquired.

Military specifications should be designed to spell out requirements that the contractor submit information to be used in planning specific items of training equipment, in preparing engineering recommendations for the equipment, and in developing and producing the individual items. These requirements should cover the preparation of performance specifications for designated developmental prototypes, and detailed procurement data for production-procurement of approved items.

A report based on training equipment development data should present the contractor recommendations for the training equipment considered necessary to support the system. It should be based on the latest operational and maintenance concept, QQPRR, and personnel and task and skill analysis data of operator and maintenance tasks and jobs in relation to the equipment they will use. This report should include (see flow chart blocks under Training Equipment Requirements, Figure B-2):

Training equipment recommendations. These should be brief functional descriptions on each item of training equipment considered necessary to support any aspect of system training, including mention of any special features that will facilitate learning, transfer of training, proficiency evaluation, etc.

Justification of training equipment recommendations. Statements should be included that:

(1) Relate the proposed training equipment items to the current status of personnel, training, operations, and maintenance concept.
(2) Identify the training functions to be accomplished.
(3) Justify the equipment in relation to the alternative forms in terms of cost; ease of modification, maintenance, and installation; versatility; and training value.
(4) Specify the types of training for which each item is proposed, such as factory, individual, and unit proficiency.

Special problems. Attention should be focused on any special considerations associated with the items being proposed, such as exceptionally long lead time required, unresolved state-of-the-art problems, or special installation or facility requirements.

Individual and unit training are typically supported by several different types of training equipment, such as simulators, operational procedure trainers, demonstrators, animated panels, and various training aids. An additional requirement imposed by the training program consists of the development of procedures for measuring and recording the performance of personnel during training. Technical proficiency tests and job performance evaluation measures must be planned in relation to the training equipment. Consideration must also be given to requirements for user training to provide refresher, transition, and upgrade training for operational readiness development, evaluation, and proficiency maintenance.

In training equipment development, specifications for equipment performance should be prepared for each item of training equipment designated by the Army. These specifications describe major design characteristics and may require the incorporation of training features, such as immediate feedback to the student of information on his performance. In addition, test recommendations and criteria are to be submitted by the developer, and spare parts information is to be supplied.

Programs of Instruction (POI's)

Training and training equipment planning operations contribute jointly to the development of the necessary Programs of Instruction. The development of POI's and the data to support them has been discussed earlier (see pp. 54-57, Appendix A). During system development, human factors training specialists on the staff of the Training Monitor will be closely involved with contractor personnel responsible for the collection and analysis of data essential for building the training programs and, if applicable, the programs themselves. They will assure application of the most recent state-of-the-training-art principles, from identification of valid training objectives to development of reliable, valid, scorable job proficiency tests. The resulting programs will incorporate the use of training equipment approved for development.

Technical Publications

In accordance with appropriate military specifications, or work statements, the contractor may be required to develop maintenance and operational procedures and techniques for incorporation in preliminary manuals that will be capable of supporting the engineering and service test programs. (See flow chart block under Technical Order and Technical Manual Requirements, Figure B-2.) Both operating instructions and servicing instructions are required. Changes and revisions will be made throughout system development, and the contractor will provide final manuals as a part of the operational system. Concurrently, charts, manuals, checklists, and other training and job performance aids must be prepared.

Periodic Inspections

Effective management procedures in the development of any system must provide for periodic checks on developmental progress and industry compliance with contractual requirements. Change 1, 17 January 1961, to AR 705-5 cites as action points or stages for major decision, such milestones as completion of the engineering concept, completion of design characteristics prior to release of design for development, receipt of the first prototype, and completion of engineering test. These are the types of conferences or inspections at which human factors specialists may either contribute their special knowledge or acquire useful information for planning subsequent personnel support system processes or products.

Human Factors Inputs to the System Test Program

The over-all objectives of the test and evaluation program for new and modified systems should include test and evaluation of the personnel support system functions. (See final flow chart block in Figure B-2.) Achieving these objectives requires continuing investigation of system equipment in relation to the intended operational environment and various human factors aspects. These include man-machine compatibility, human factors engineering design, personal and protective equipment, physiological factors, qualitative and quantitative personnel requirements, training and training equipment requirements, and manning and organizational requirements. Through the system testing program, early consideration may be given to needs of system personnel for performance aids, for OJT aids, and for evaluation devices to be used in measuring personnel performance and proficiency.

The primary objectives of the personnel support system test program are:

(1) To determine whether the system is capable of being operated, controlled, and maintained by Army personnel programmed for the system.

(2) To determine whether personnel performance is adequately supported by the proposed, planned, or established equipment design, technical data, job environment, training, organizational control procedures, personnel selection, manning, etc.

(3) To identify problem areas and deficiencies that can degrade system effectiveness, so that timely corrective action can be taken.

To ensure that the PSS is effectively evaluated in terms of over-all system test objectives, a coordinated Personnel Support System Test Plan should be developed by professionally qualified human factors specialists. It should be published with or as an annex to the over-all system test plan. It should identify the numbers and kinds of test team specialists to be supplied by the developer, schools, and user, and by contractors, and specify the test objectives, requirements, and responsibilities.

A personnel support system test program officer should be appointed to serve as chairman of the PSS test team under the Chief of the over-all test program. Members of the team will consist of representatives of the major functional commands as specified in the PSS test plan. This team represents that portion of the total test organization that plans, organizes, coordinates, directs, and supports the collection of PSS test and evaluation data. It analyzes and evaluates the data, initiates corrective action on items having PSS implications, and prepares a PSS Test Report.

The PSS test and evaluation team may employ such devices as checklists, evaluation guides, task analyses, laboratory experiments, questionnaires, interviews, ratings, and paper-and-pencil tests. All performances required of personnel in the system will be observed and evaluated. Troubleshooting tasks may be tested whenever malfunctions occur during the hardware test program, or by introducing malfunctions in selected critical areas. When any deviation or difficulty is observed or reported, the test team investigates the problem and takes corrective action.

When test priorities arise, critical operations are given first priority for data collection purposes. For the most part, the operational and technical requirements of the system, including the operational and maintenance concepts, are used as criteria against which to assess the adequacy of the personnel support system processes and products. The test program should progress from subsystem testing to system testing, and, ultimately, to evaluation of human performance in the operationally configured system during simulated missior ɔɪnplishment.

Human Factors Inputs During the Operational Stage

The operational stage of a weapon system begins with the delivery of the first production unit, complete with trained personnel, to the using agency. Extension of the personnel support system concept into the operational stage may occur in several ways:

(1) Training of replacements due to normal attrition in skill inventories.

(2) Human factors engineering design modifications resulting from operational experience or advances in technology.

(3) Modifications of training equipment to keep current with changes in system capability.

(4) Development of new training equipment or attachments to operational training equipment to increase training and/or evaluation capability.

(5) Additions to, or revisions of, job performance aids as a result of operational experience.

Conclusion

The foregoing has described systematic procedures for the development of a Personnel Support System and its products and processes integrally with the development of a weapon system. Systems engineering must provide for the time-phased development of data required for producing human factors engineering criteria, personnel requirements, training plans, training equipment, technical manuals, and testing programs.

However, for personnel support system data requirements to be met adequately, there must be an effective data program for the management of total system development. If the various elements of the personnel support system, as developed by many Army and/or contractor departments and agencies, are to form an operative system, it is imperative that data be developed systematically, with inputs correctly time-phased for use in meeting all requirements. The same basic data must be used in developing all end products if compatibility is to be achieved in concurrently developed products. Such a basic data program is not covered by existing specifications.

In addition to the specific points described in this appendix, Figure B-2 illustrates two more general aspects:

First, the personnel support system products and processes, with their specific dependencies and interdependencies, all of which ultimately have their origin in the basic data pool.

Second, a requirement for appropriate Army agencies to develop, or identify where they now exist, accurate specifications as to what is required for the management, control, or production of each of the elements of the PSS illustrated as requiring a Spec. No.____. The reorganization of the Army currently underway would seem to provide an excellent opportunity to standardize specifications, so that the number a contractor must observe could be held to a minimum while the Army's requirements would nevertheless be fully and accurately stated.

Appendix C

PROPOSED DIRECTIVE FOR INTEGRATED DEVELOPMENT OF HUMAN FACTORS DATA

R&D DIRECTIVE)
No. ____________)

Research and Development (General)

Human Factors Engineering and Personnel Support
System Products in Development Contracts

1. It is the policy of the Department of the Army to apply the principles of human factors engineering and to require the concurrent and integrated development of Personnel Support System products in the development of weapons and equipment, in order to assure maximum effectiveness of the man-machine combination in the operational environment.

2. Research and development contracts for materiel and equipment which require human activities for operation or maintenance shall specifically require the contractor to perform competent professional human factors engineering and to produce human factors data basic to Personnel Support System end products. Some of these products, as specified in par. 5 below, the contractor will develop under monitorship of Army human factors specialists.

3. The human factors engineering will include but not be limited to a consideration of the following (where applicable) in terms of the intellectual, physical, and psychomotor capabilities of the intended user:

a. Proper assignment of functions to machines and to operators.

b. Human space requirements for operation and access for maintenance.

c. Planning of operator functions and analysis of operator tasks.

d. Layout of work space and design of operator stations.

e. Information needed for operator decisions, e.g., selection of displays and controls.

f. Environmental conditions, e.g., temperature, noxious gases, noise, vibration, illumination, stress.

g. Compatibility of the equipment with the personal and protective gear of the fully equipped soldier.

h. Communication under operational conditions.

i. Simplicity of maintenance.

j. Safety in operation and maintenance.

4. The human factors data basic to Personnel Support System end products will include but not be limited to the following (where applicable) in terms of the intellectual, physical, and psychomotor capabilities of the intended user:

a. System functional description.

b. Operational plan.

c. Maintenance and logistics plans.

d. Task and skill analysis data.

5. The Personnel Support System end products, which the contractor will develop completely, will include but not be limited to the following (where applicable):

a. Qualitative and Quantitative Personnel Requirements Reports.

b. Training Programs of Instruction, to include identification of training objectives, development of content and recommended training methods, and preparation of job proficiency tests for training quality control.

c. Training of key personnel to support engineering and service tests, and the development of further detailed POI's.

d. Training equipment requirements, complete with justification and in sufficient detail to show how the proposed equipment will meet the need.

e. Training equipment development.

f. Technical publications and job performance aids, e.g., checklists, procedural guides.

6. Developing agencies will ensure that human factors engineering principles are incorporated into the design of the initial prototype, and that the Personnel Support System data and end products are developed integrally and concurrently with it.

BY THE DIRECTION OF THE CHIEF OF
RESEARCH AND DEVELOPMENT:

Appendix D

PLACES VISITED FOR COLLECTING INFORMATION FOR PREPARATION OF THE *UPSTREAM III* REPORT

Date	Places Visited	Agencies
1959		
August	Lackland Air Force Base	Personnel Research Laboratory
	Randolph Air Force Base	Hq, Air Training Command
	Eglin Air Force Base	Hq, Air Proving Ground
September	Wright-Patterson Air Force Base	Training Psychology Branch
1960		
June	The Adjutant General's Office	Systems Development Branch
	Aberdeen Proving Ground	U.S. Army Ordnance School
		U.S. Army Ordnance Center
		Human Engineering Laboratory
	Department of the Navy	New Developments Research Branch
	Redstone Arsenal	Army Guided Missile Agency
		Ordnance Guided Missile School
		Army Ballistic Missile Agency
		Army Ordnance Missile Command
September	Naval Training Devices Center	Army Participation Group
October	White Sands Missile Range	
1959-1961		
Continuing visits	Army Air Defense Center	Air Defense Board
		Air Defense School
		Combat Developments and Research

Appendix E

A REVIEW OF RESEARCH ON THE PREDICTION OF PERSONNEL AND TRAINING REQUIREMENTS[1]

In recent years, the rapidly increasing complexity of new weapons, equipments, and systems has resulted in unique and urgent demands for research in the area of training requirements for maintenance, support, and operator personnel. As a result of these demands, extensive research has been performed in the general area of training requirements forecasts.

In 1950, Miller and associates at the American Institute for Research began a series of studies concerning the prediction of personnel and training requirements. In 1953, the report of the first of these studies was published (6). In it Miller suggested a method for anticipating maintenance requirements in the early stages of the development of a weapon system, primarily from information available during or prior to the prototype stage of a new weapon. This method is based upon the concept of maintenance as a man-machine system with identifiable purposes; once these purposes are explicitly stated, the activities required to achieve them (including maintenance job behaviors) can also be specified.

Two applications of the procedure were made to determine its effectiveness and usability. The first application was made on the AN/APQ-24 Radar Set, and the second on the K-1 Bombing Navigational System (10,11). These applications were concerned primarily with the adequacy, or validity, of this procedure in anticipating maintenance job requirements. Both were conducted on equipment that had been in use for some time, but utilized only that information which would have been available during the prototype or earlier stages of production. The results indicated a high degree of similarity between job requirements for the production model and the prototype model. It was concluded that equally good or better prediction could be obtained if the procedure were applied to new equipment. An actual chronological anticipation of task requirements was attempted and found to be highly successful. It was suggested that the same procedure be applied to equipment that would be in use in the future.

In 1953, Miller (7) described a procedure that was designed to specify training requirements for equipment operators in detailed and clear-cut terminology. This procedure was intended for use in the blueprint and breadboard stages of development, as well as in later

[1]References cited are listed at the end of this appendix.

stages. Miller considered the operator as a part of the system's linkages, with input and output functions. The tasks were specified as procedural or tracking. Miller's procedure involved the analysis of equipment, or designs for it, for the identification of operator tasks imposed by its configuration. Further analysis of these tasks (task analysis) revealed their characteristics and the demands they would place upon operators. From this information, training content and method could be planned. In addition, tasks for which training devices would be required were identified, and the nature and functional characteristics proper to the devices could be inferred as an aid in preparing design specifications for them.

Another report (12) was concerned mainly with the following three items: (1) What maintenance information should be collected, and from what sources? (2) At what stages in the developmental sequence is it feasible to collect information for job-forecasting purposes? (3) How can maintenance information be assembled for the anticipation of maintenance job requirements? The report also contained a description of six maintenance duties on which information is required before the duties could be performed effectively: checking, adjusting, repairing, replacing, servicing, troubleshooting.

The report suggests that practical forecasts can be made prior to the completion of prototype models. In order to anticipate maintenance job requirements of a weapon system, so that trained mechanics will be ready to maintain the system when it becomes operational, maintenance information must be gathered from a variety of sources. These sources were described as products (specifications, diagrams, test reports, etc.) developed during the building of the system.

Two reports published by Miller in 1956 (8,9) suggest procedures for the development of position[1] structures and position organization tables. This can be done at the time a newly developed weapon reaches the stage of operational concept and operational plan. The suggested procedures, which have been given a trial, represent a means of systematically developing information needed for personnel and training actions. These actions must be planned and accomplished before a new weapon system can be introduced into the field. The procedures suggested in the report provide data but not complete answers to all the problems presented. These procedures (position-task analysis) indicate what has to be trained, but not the best way to undertake the training. The subsequent utilization of data provided by position-task descriptions and analysis requires the use of principles already in existence and assistance from specialists trained in the area under investigation.

Throughout the report an attempt was made to show that the gathering of Qualitative Personnel Requirements Information (QPRI) and the making of Qualitative Personnel Requirement (QPR) decisions is a continuous and cumulative enterprise. It was also pointed out that the gathering of QPRI data and the making of QPR decisions are subject to

[1]This research was performed for the Air Force, which uses the term *position* to indicate a grouping of duties and responsibilities which comprise the principal assignment of one person.

tentative and provisional inferences, plans, and decisions, just as is the development of the hardware aspects of a weapon. A division of QPR continuity into phases for the purpose of coordinating and meeting certain schedules was suggested. This should not, however, imply an intermittent effort in preparing for the design of personnel and training programs. The practical advantages of keeping QPRI data continuously up to date seems clear.

Later in 1956, Naureth and Kelly (13) reported a prototype task-equipment analysis based on the job of the F-104 hydraulic system mechanic. This analysis was to be used as a model and should not be considered to have application to the F-104 system only. The report suggested the necessity of a task equipment analysis during the latter stages of a system development to assist in (1) preparation of detailed content materials for formal training courses, and (2) development or revision of tests which will be used to measure proficiency. It was also suggested that a task-equipment analysis should contain a description of the duties of the job; a general description of the subsystem, components, tools, and test equipment which apply to the job; and a specific account of the activities required for each job task.

The data for this prototype were obtained from the system development contractor. The source materials included training handbooks, parts catalogues, and preliminary drafts of the maintenance handbook.

Early in 1957, Ray et al. emphasized in a report (15) that adequate information concerning a new weapon system should be communicated to those charged with meeting support demands in advance of the production of the new system. This information is necessary if support personnel are to be available in sufficient numbers, at proper locations, and with the knowledge and skills required to maintain the system effectively.

The report is concerned with a description of a technique for communicating personnel and equipment information. This technique provides information of a more detailed nature than various techniques already in existence, such as the QPRI. Such detailed information, describing how the tasks are to be performed, is essential in the planning and construction of courses of training, as well as in the re-evaluation of manning requirements, the development of proficiency measures, and the preparation of handbooks. Because this technique relates maintenance duties to equipment on which they are to be performed, the technique is called Task Equipment Analysis (TEA). Although this procedure was intended for maintenance positions (as opposed to operator positions), it may be applied to operator jobs with slight modifications.

The initial phase of this technique involves a functional analysis of the weapon system as a whole, and is properly entitled an equipment analysis. This phase is limited to a description of the operation of the principal subsystems and their components. The second phase consists of an analysis of the weapon system in terms of the tasks involved in the maintenance of the system, and may be termed a task analysis. During the latter stage, emphasis is placed on deriving the activity elements (the action, the objects, the indicator, and the indication) and describing what the man (rather than the equipment) does. The report included samples of adequate and inadequate task descriptions, to facilitate the development of descriptions that are behaviorally oriented and complete. Also included was a useful cross-index of equipment components and job duties.

A study by Goody (4) attempted to determine whether a course of training could be adequately planned from job descriptions based upon task-equipment analysis of a system obtained during the developmental stage. This report is concerned mainly with whether the available task-equipment analysis contained the necessary information for detailed course planning or whether it would be necessary to return to a study of the hardware and its specifications for further information.

It was concluded that a course of study could be so developed. There appear to be few, if any, differences to be considered in setting up a course of training based only on such a job description and one based on direct study of the problem device. The same psychological principles hold, and differences in technique are easily grasped after a little practice.

Glanzer and Glaser (2) evaluated the feasibility of predicting personnel and training requirements for new weapon systems. Statements concerning these requirements which had been made five years previously on the basis of a prototype system were checked against data obtained concerning final models of the system in operational use. The results indicated acceptable reliability, with coefficients ranging between .72 and .99. These ratings indicated that, in general, requirements developed on the basis of a prototype system remained applicable with minor modification over the five-year period.

The report stated that material concerning operation showed somewhat greater stability than material on operational maintenance, and the highly specific material in the areas of troubleshooting showed the least stability. The report also indicated that the material concerning the missile itself was more stable than material for the associated test equipment.

A HumRRO report by Shriver from Task FORECAST (16), published in 1960, was concerned with the development and testing of methods for the analyses of electronic weapons systems, to define a set of skills and knowledges for operating and maintaining the systems. It was hoped that the methods of analysis, which in this study were used on the M33 Antiaircraft Fire Control System, would prove adequate for future weapon systems.

The training program developed for the M33 was based on the type of information available before the production stage, even though the M33 was an operating system at the time the study was made. Two methods for the analysis of electronic equipment were developed, one for the operator task and one for the maintenance task. These methods were designed to identify a set of skills and knowledges and their constituent parts: cues, or what a man perceives, and responses, or what he does about it.[1] Both the cues and the responses ranged from the very simple to the very complex. When properly learned, these cues and responses could form the basis of a logical reasoning process that would lead to effective operation and maintenance of the weapon.

As evidenced by the results, analysis of this type (cue-response) appears to be very effective for training under conditions somewhat more controlled than most Army instruction. The experimental group was composed of 20 students who came directly to the 12-week experimental course from basic training. The standard group was composed of 17 students who went directly into the standard 30-week course from basic training. After graduation, both groups were tested on an objective performance test requiring nine days per student for completion. The results show that there were no practical differences in proficiency between the experimental and the conventionally trained group.

On the basis of the foregoing information, it seems clear that personnel requirements information for the purpose of training personnel to operate and maintain new weapon systems can be acquired at the developmental stage of the weapon system. The research performed in this area suggests not only that this is possible but that it is also practical. It seems reasonable at this point to recognize the possibility that job forecasting techniques can be utilized as an aid in reducing the lag between the time a new weapon system is produced in large numbers and the time personnel can be trained to operate and maintain the system. The data resulting from these techniques will also be useful in the areas of selection procedures, training content, and training devices, and in the school administration of training.

It also seems possible that the utilization of job forecasting techniques during the development stage of a weapon system may have practical implications other than those of training forecasts. Possible additional developments include: (1) techniques of troubleshooting procedures which can use parts failure probability data if available, (2) recommendations for equipment design that could very possibly lead to improved maintainability, (3) procedures to be used for data collection purposes, as well as concepts for using such data in monitoring and improving complex man-machine systems and organizations, (4) data on maintenance problems which may occur in operations and training, and (5) standardization of a format to be used in compiling intelligible technical orders.

In 1960, Rabideau and Cooper (14) presented a state-of-the-art description of function and task analysis method, and an approach to using this type of analysis as a weapon system development tool. The main premise was that function and task analysis is a method by which the analyst can correlate and organize the data that are inherent in the development of a weapon system. This makes possible the logical

[1]For further information, see Edgar L. Shriver, C. Dennis Fink, and Robert C. Trexler, *A Procedural Guide for Technical Implementation of the FORECAST Methods of Task and Skill Analysis*, Training Methods Division, Human Resources Research Office, Washington, July 1961.

derivation of the design of man-machine functions, the task groupings, the definition of positions, and the manning requirements for the weapon system.

Later in 1960, Folley et al. (1) reported a survey of methods for predicting personnel requirements for future Air Force weapon systems. This report contained abstracts of 121 unclassified professional documents with emphasis being placed on identifying procedures for deriving personnel requirements information, and the supporting rationales. The report also contained an evaluation of the current state of the art and implications for future research requirements. It was concluded on the basis of this study that fairly thorough procedures exist for describing tasks and positions and for combining tasks into positions.

Since the American Institute for Research had done considerable work in the area of forecasting training requirements for the Air Force, HumRRO requested a review and summary of their work by contract under UPSTREAM II. In addition, AIR was to apply the best of the methods and procedures derived from this study to the HAWK system prior to its reaching prototype stage. Both aspects of the work are reported in Goldbeck and Kay (3).

The HAWK study yielded results that are not profound as we understand system development today. The best information sources were identified as interviews with contractor technical personnel, reports and publications (which were mainly engineering oriented), and mockups and models. The problems identified, in applying the procedures to a study of the HAWK, were as follows:

(1) No man-hour costs for such purposes had been included in the system contract, so contractor cooperation was poor.
(2) There was difficulty in establishing a good working relationship between the analyst and appropriate knowledgeable personnel.
(3) It was difficult for the analyst to gain access to pertinent information.
(4) The analyst had trouble establishing and maintaining adequate liaison with appropriate training agencies.

It would appear that these problems could be resolved by including, in the prime system contract, a requirement for developing both the hardware and its personnel support system materials. This should have the following effects: (1) Under the contract the work would be funded; (2) the training analysts would be on the contractor's staff; (3) they would have access to all required information; (4) they would have liaison with the training agencies through the military monitor and coordinators.

A recent report of Air Force research provides an indication of the gradual maturing of procedures as practiced there. Losee et al. (5) have developed a method for an accurate and comprehensive forecasting of manpower requirements for new weapon systems. The manning estimate is developed through a series of integrated steps leading to position descriptions and numbers of men required. Early training information is obtained directly from Task Equipment Analyses;

information covering ground support and other equipment, spares, and consumables is obtained as a by-product. Plans are presented for an approximation of the effect of environment upon manning requirements, for the determination of man-hours required for work of a type not amenable to direct task analysis, and for the estimation of maintenance activity frequency rates.

The extent to which the methods described have been tested is not stated in this report. They appear, however, to be systematic, thorough, complete, and workable and merit the careful examination of any agency faced with the requirement to develop a personnel support system for a weapon under development.

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Appendix F

SPECIFICATIONS FOR TASK ANALYSIS

This appendix contains a simplified set of specifications for Task Analysis, aimed at achieving mutual understanding by both parties to a human factors contract, as to the objectives and the desired products.

These specifications are based on a work statement originally prepared for a particular missile contract which is replete with excellent, detailed instructions on how to make function and task analyses. These details, while invaluable for a work statement, were considered too voluminous for reproduction here, where the purpose is to illustrate specifications defining the scope of work and the variety of activities required in making and verifying a complete analysis. The abbreviated specifications in this appendix could, at least in the main, be readily adapted for use with a wide range of weapon systems. The detailed guidance necessary would be available in the document from which this appendix has been extracted: Space Technology Laboratories, Inc. Revised Work Statement: Personnel Subsystem Basic Data Program for the Atlas Missile, GM 6300.5 5-653, Los Angeles 45, Calif., 12 August 1960.

Specifications for Task Analysis

I. Scope

The purpose of this exhibit is to describe the information that must be developed by the contractor to inform Army personnel and training agencies of the anticipated personnel, training, and training support requirements which will be imposed by the operational use of a new weapon system. This information will serve as a basis for planning, programming, and accomplishing development of a personnel support system for the new weapon system prior to the receipt of the actual hardware. This exhibit includes the task analysis procedure, reporting requirements, and verification procedures.

II. Task Analysis

Task analysis is the process of identifying what job operations, tasks, and task elements must be performed, what the requirements and conditions are for their successful accomplishment, who does them, and where and when they are done. The Task Analysis procedure requires (a) an analysis to identify system functions; (b) a more detailed analysis to identify the specific tasks required to render the system operational, to maintain this condition, and to fulfill the system's mission; and (c) a still more detailed analysis to identify and select the equipment, personnel, training, and job aid requirements for the performance of each function so identified.

1. System Description, Function Identification, and Flow. This section shall include the identification of the functions and operations which must be performed by the weapon system components and equipment, or performed on them by personnel, in order to assure that the weapon system is operational.

1.1 Operational characteristics. A summary of the operational characteristics of the weapon system.

1.2 Maintenance and operational concepts. A brief narrative description of the anticipated method of operation and support for the weapon system, subsystems, and components. This description shall outline the basic concepts determined by such factors as unique or built-in test equipment, replaceable assemblies, expendable components, automatic malfunction indicators, and the like.

1.3 Equipment description. A list and brief description of the major hardware subsystems showing their function and relation to the total weapon system. A dated statement of the developmental status of each subsystem shall be included.

1.4 Task sequence summary. A listing in temporal sequence of the duties and tasks involved in the weapon system activities, from the time equipment leaves the manufacturer until it is used for its designed purpose.

1.4.1 Pictorial representations shall be used to illustrate work flow. In addition, functional diagrams shall be provided to depict the sequences of organizational, technical service, and depot operations, locations, and interactions of personnel functions, including the support equipment employed to perform these functions. Flow charts should be furnished for the following general functions:

1.4.1.1 Identification of personnel operations or man-machine interactions associated with the transportation, receipt, inspection, installation, checkout, launch, tracking or guidance, acquisition, readout, and so on, of the weapon system. The above operations refer only to normal weapon system activities, assuming no malfunctions are encountered and no repairs are necessary.

1.4.1.2 Identification of personnel operations performed during periodic maintenance of equipment and associated support equipment, as appropriate for using organization and technical service.

1.4.1.3 Identification of personnel operations involved in checkout, troubleshooting, and repair of the system support equipment, and special facilities.

1.5 <u>MOS requirements summary</u>. For each job operation identified above, the following information shall be presented in tabular form, and in temporal sequence where appropriate:

1.5.1 List the tasks.

1.5.2 Following each task, indicate the Military Occupational Speciality (MOS) title and number of personnel required to perform the task.

1.5.3 Where team performance is necessary, specify the composition of the team. Insofar as possible, distinguish between the requirement for a skilled mechanic or technician and the requirement for a "pair of hands."

1.5.4 The total time required to perform or accomplish the job operation.

1.5.5 When possible, indicate the nature of any special equipment required.

1.6 <u>Manpower requirements</u>.

1.6.1 The number of suitably trained individuals required to perform the tasks of each MOS per work period shall be estimated. Where appropriate, these estimates should be broken down into major work areas or sections. Definition of supervisory positions shall be included.

1.6.2 Each manning report following an earlier report shall contain a table with comparative listings of MOS's contained in the previous report.

2.[1] <u>Task Description</u>. This section shall explain what is analyzed to describe a task, as well as to supply other essential

[1]In presenting the content of this section, it was assumed that the reader is a professionally qualified human factors specialist.

information derived from a detailed analysis of the conditions and requirements for task performance. This will assist equipment de-¹gners and training, training equipment, and technical manual ,.rsonnel in establishing requirements and preparing detailed materials in their respective areas.

2.1 The start and end points of the task.

2.1.1 Is the task preceded by another task?

2.1.2 What is the cue used by the performer to determine that the task must be performed?

2.1.3 What cue or feedback is available to the performer to determine that the task is completed?

2.1.4 Is the task followed by one or more tasks, sequentially related?

2.2 Pre-task activities or duties.

2.2.1 Does performance of the task require the prior performance of other complete tasks?

2.2.2 Are any communications required to authorize the performer to proceed with the task?

2.2.3 Are any safety precautions required to relieve pressure or shut down power, and so on?

2.3 Characteristics of the task. The task characteristics and their sequence shall be identified. This refers to the step-by-step procedures for performing the task, including any precautions, aids, or alternate procedures that may possibly be used.

2.4 Personnel required to perform the task. The specialists and helpers required to carry out the task shall be identified by MOS, and their roles in performing the steps or elements shall be stated.

2.5 Tools and test equipment. Statements describing each task element shall include mention of any standard and/or special tools and test equipment that must be employed.

2.6 Aids required for task performance. Aids such as checklists, schematics, flow diagrams, test specifications, illustrations, and so forth, designed to simplify knowledge and skill requirements of trained personnel, shall be listed for each task.

2.7 Elements of the task that are difficult or hazardous to the equipment and/or personnel.

2.7.1 Hazard to equipment and/or personnel shall be determined and stated on a "what happens if" basis.

2.7.2 Difficulty of elements of the task shall be defined in terms of:

2.7.2.1 The sensory motor skill required. (Probable human error in operation and maintenance of the weapon system.)

2.7.2.2 The analytical demand of the task. (Out-of-commission time for system troubleshooting.)

2.7.2.3 The tolerances required. (Probable human error and/or incorrect choice in logistics support planning.)

2.7.2.4 The likelihood of creating a hazardous condition. (Catastrophic failure of equipment and loss of human life.)

2.8 <u>Length of task performance</u>. A verified (see p. 98) estimate of the time required by fully qualified specialists to perform a task involving fixed procedures shall be presented. The time required to perform a task involving variable procedures may cover a considerable range, even for highly qualified specialists. For such a task, the attempt must be made to estimate a mean time for performance and to verify it if possible.

2.9 <u>The performances that are critical to successful task completion</u>. Critical performance requirements shall be identified to establish how training, training equipment, technical order, job performance checklists, and evaluation in the standardization program must be oriented to ensure development and maintenance of task proficiency for successful human accomplishment.

2.9.1 Time limits in the performance of the task. In the performance of the task, or some elements of the task, are there prescribed time limits that must be met, even if a high degree of skill is required to meet them?

2.9.2 Precise adjustments. List any precise adjustments that must be made even if they are difficult to achieve.

2.9.3 Safety precautions. List any safety precautions that must be observed to avoid risk of endangering personnel or equipment.

2.9.4 Clear and precise communication. State any requirement for clear and precise communication, which, if not achieved, might result in mission failure, unnecessary degradation of equipment, or excessive down time.

2.9.5 Conditions giving rise to emergency situations. State any condition that could arise requiring a quick and exact response to deal with an emergency situation, which, if not handled correctly, would cause personnel injury, system degradation, or catastrophic failure.

2.9.6 Detection of contamination and equipment damage or degradation. State any possibilities to be avoided for contamination, equipment damage, or degradation, which would be hard to detect by routine visual inspection or check-out procedures, and the effects of which would become evident only at a later date or when a system is committed to an operational launch.

2.9.7 Criticality of the performance of certain steps to the system operation. Specify any steps, sequence, or possibly timing of performance that are essential in order not to cause undue delay or degradation in the system operation.

2.9.8 The criticality of individual performance. If coordinated effort between individuals is required, such that if one fails to perform correctly the correct performance of another is jeopardized, make a statement to this effect.

2.9.9 The criterion of successful performance. Given the end points of the task, and the critical performances, within what limit must the task elements be performed in order to assure mission fulfillment?

3. MOS Definitions. This section shall define all types of Military Occupational Specialties (MOS) that are directly associated with the weapon system. The following criteria shall be used for defining a position (by Army definition, duty positions with close occupational or functional relationships are grouped to comprise on MOS):

3.1 Locality of task performance. The MOS shall be characterized by performance of work in designated locations on specified equipment or equipment systems; as a consequence, the tasks are essentially independent from those performed on equipment at other locations, or the task relationships with the other locations are only by communication links and/or procurement and transportation of equipment and materials from one location to another.

3.2 Requirements for specialized knowledge and skills. An MOS shall be required if specialized knowledge and skill requirements for operation, control, and maintenance of subsystem equipment will be great enough to justify a separate training course.

3.3 Physical interconnections of items of equipment. An MOS shall be required if items of equipment or equipment systems are not physically interconnected and the scope of knowledge required for any one item or system is great enough to justify a separate training course.

3.4 Work load. Tasks comprising an MOS shall constitute a full-time work load.

3.5 Task interrelationship and interdependence. Tasks to be accomplished shall be interrelated and interdependent, so that each MOS can be identified as a distinct entity.

3.6 Task aptitude. Individual tasks within the MOS shall have similar aptitude demands for acquiring the required knowledges and skills.

III Reporting Requirements

Contractors shall analyze their products and submit data and recommendations as directed herein.

1. Analysis Worksheets. The analysis worksheet shall contain the records of detailed analysis of tasks approved for such treatment. These analyses should be maintained at the contractor's facility, subject to review and approval by an Army monitoring group. In a case where two or more associate contractors

identify tasks that require joint analysis because of equipment interface relationships, they shall mutually agree upon and work out a joint analysis of the task. The worksheet shall contain the following information:

1.1 Task numbering system. The task under analysis shall be numbered systematically for identification purposes.

1.2 Task title. The task shall have a title which will be listed in a task index along with the appropriate number.

1.3 Analysis dates. The dates on which the various stages of analysis are performed shall be given.

1.4 Location of task performance. The location or environment where the task is performed shall be identified.

1.5 Verification level. The status of verifications of the task information shall be given. The following terms shall be employed:

1.5.1 "Estimated," if the information was based solely on an "armchair" estimate of task performance which has been reviewed and approved by design engineers.

1.5.2 "Tried," if the information has been based on a walk-through or mockup performance of the task on mockup, simulated, or prototype equipment.

1.5.3 "Final," when the task has been fully observed as performed by qualified personnel on operational equipment in an operational environment. Simulation of operational conditions is acceptable for final verification of the task, provided the conditions are identical to those which will be found in the operational use of the equipment.

1.6 Task time. An initial estimate of the amount of time permissible for completion of a task which is critical to the operational status of the system shall be given. Following verification, and with follow-on operational experience, task time standards shall be established by repetitive task performance which provides a more precise estimate of the mean time required for a properly qualified specialist to perform the task. The two types of entries shall be clearly distinguished to indicate the meaning of the specific entry.

1.7 Speed. The criticalness of the speed required to perform the task within a given period of time shall be stated.

1.8 Frequency of performance. An estimate shall be given, by day, week, month, or other measurement, of how frequently the task will be performed for a unit of equipment as defined by operational and maintenance requirements.

1.9 Personnel required. When possible, the military position titles preceded by their MOS numerical designator shall be given. The number of personnel of each MOS required to accomplish the task shall also be indicated.

1.10 Organization responsible for the task. The organizational element responsible for the task performance shall be identified (e.g., launch crew, mobile checkout, and maintenance teams of each section).

1.11 Task description. The nature, conditions, and requirements for task performance shall be stated. The description shall contain as a minimum the following:

1.11.1 A statement of the starting cues for the task being described, which indicate that the task is to be performed, and any steps to be taken before the task can be performed (e.g., supervision notified, power supply turned off, area cleared of personnel).

1.11.2 Decision-making requirements. An explanation of what has to be done and how to do it, down to the lowest level, with special emphasis on any decision-making requirements.

1.11.3 An explanation as to the personnel required to do the task and the location of the task. When two or more people are required for task performance, the task activity shall be described sufficiently to indicate the role of each position; the interaction required and the type of communication and coordination among personnel shall be specifically described, including any special equipment required for communication.

1.11.4 Tools and test equipment. A list of tools and test equipment required for the task performance, and a statement as to whether these items are standard or special.

1.11.5 A description of any unusual human factors elements (e.g., the task is performed in an unusual position, such as a prone position; the task performance results in extreme fatigue, strain, or stress; the task requires personnel to be exposed to extreme weather conditions for long periods of time; task completion requires the personnel to stand, or be confined in close places, for long periods of time).

1.11.6 Criticality of task performance. A description of any aspect of task performance that may be critical to the successful completion of the task (e.g., sequence of procedural steps to be strictly followed, performance within a prescribed time limit, correct interpretation of relative status of indications).

1.11.7 A description of the feedback that indicates when the task has been accomplished completely and accurately.

1.12 Probable error factor. The probability of human error due to the nature of the task itself or the environment in which the task is performed shall be stated, with the reasons for such an estimate being described if the probability for such error is high.

1.13 Special handling. Any criticalness or care that is required in the performance of a task when handling or positioning equipment shall be stated.

1.14 Hazards. Any source of hazards that may be encountered by personnel in the performance of the task shall be described, whether due to the nature of the task itself or to the environmental conditions where the task is performed.

1.15 Special clothing required. Any special clothing requirements necessary to insure personnel safety in the performance of the task shall be identified (e.g., eyeshield, nonsparking shoes).

1.16 Procedure type. The task shall be classified as to the nature of procedure. For example:

1.16.1 Fixed procedure: Task elements are performed in a routine step-by-step sequence that could be listed in a technical manual, or checklist, for use on the job.

1.16.2 Variable procedures: Task elements (two or more) are not performed in a fixed sequence but all must be performed to achieve a final result, such as the alignment of two circuits. The procedure is complex because the individual must estimate the correctness of the indications for each particular step, rather than make a simple identification. Following such an indication, the individual may be required to decide upon appropriate action to be taken in the succeeding step.

1.16.3 Motor skill: Accomplishment of the task depends primarily upon acts requiring physical skills, which have not been previously learned by the individual but which must be learned in order to perform the task correctly.

1.16.4 System analysis: A malfunctioning component, assembly or module is located by means of logical analysis of data flow.

1.16.5 Circuit analysis: A malfunction within a detailed part or a component of an assembly is isolated by logical analysis of circuit diagrams or schematics and the use of various pieces of test equipment.

1.17 Manipulation of controls. Each type of control that must be manipulated in performing the task, and the type of feedback that must be monitored, shall be indicated.

1.18 Special problem areas. Any unusual personnel requirement problems inherent in the proposed maintenance and operational employment of the systems shall be highlighted. The nature of the problems generated shall be described, and alternative solutions recommended.

IV. Verification

A verification program shall be developed and coordinated by the prime contractors with the assistance of the associate contractors. This section shall be a report of the status of the task analysis in relation to the changing phase of equipment design and development. It specifies procedures which assure that product development and verification proceed economically and with a high degree of competency.

1. Status of Equipment Development. A statement shall be made as to the status of equipment development related to each task, using the following code:

1.1 Design plan.

1.2 Preliminary design.

1.3 Mockup.

1.4 Prototype equipment.

1.5 Production design.

1.6 Production hardware.

2. Updating Reports on Development. The preceding information shall be updated in succeeding reports to accurately reflect the hardware development.

3. Modifications to Task Analysis Worksheet. This section shall contain the date and a brief narrative statement of the reasons for the latest modification to the task analysis worksheet for each task (e.g., change in hardware development status, change in operational plan, verification test).

4. Completion of Task Analysis Worksheet. This section shall contain the date on which all data required in the task analysis worksheet for each task have been obtained and where applicable, verified against actual hardware.

5. Verification Procedures Information. This section shall contain the following items:

5.1 Description of the methods and procedure used in accomplishing the verification.

5.2 Identification of the contractors and the Army personnel conducting and participating in the verification procedure.

5.3 An identification of the systems/equipment by which the information and instructions were verified.

ACKNOWLEDGMENTS

Numerous military and civilian personnel connected with all of the military services gave generously of their time in explaining their operations in relation to the concept of a Personnel Support System. While they are too many to name individually, their contributions were significant and are gratefully acknowledged.

While most appreciative of the assistance and information given him, the author accepts sole responsibility for the fidelity with which he has reported the materials.

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2 PSYCHOL BR ENVIRONMENTAL RES DIV
USA QM RES & ENGIN CTR NATICK MASS
2 CG USA QM RES & ENGIN CTR NATICK MASS
ATTN TECH LIB
1 PRES USA CHEM CORPS BD USA CHEM CTR MD
1 CHF APPLICATIONS SECT P&O BR TELEV DIV
ARMY PICTORIAL CTR LONG ISL
2 CO USA COMBAT DEVEL EXP CTR FT ORD
1 SIXTH USA LIB DEPOT PRES OF SAN FRAN
1 CHF DEPT CLIN & SOC PSYCHOL WALTER REED
ARMY INST RES WALTER REED ARMY MED CTR
2 CG FT ORD
1 DIR WALTER REED ARMY INST RES
WALTER REED ARMY MED CTR
1 DIR WALTER REED ARMY INST RES WALTER
REED ARMY MED CTR NEUROPSYCHIAT DIV
1 CO HQ USA ENLISTED EVAL CTR
FT BENJ HARRISON
1 CO US ARMY MUN COMD FRANKFORD
ARSENAL ATTN SMUFA 031 69 1
1 DEFENSE SUPPLY AGY ATTN LIB
3 CO US ARMY ARMOR COMBAT DEVEL AGY
FT KNOX
2 LIB USA WAR COLL CARLISLE BKS PA
1 US MIL ACAD ATTN LIB
1 COMDT ARMY AVIAT SCH FT RUCKER
ATTN SCH LIB
1 COMDT ARMY SECURITY AGY TNG CTR & SCH
FT DEVENS ATTN TNG PUBS BR
1 MED FLD SERV SCH BROOKE ARMY MED CTR
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ATTN ESSY L
1 DCS PERS DA ATTN CHF C&S DIV
3 DCS MIL OPNS DA ATTN CHF TNG DIV
1 CHF INFO DA ATTN CHF TI DIV
1 OFC CHF ORD R&D DIV ATTN ORDTB
RES & SPEC PROJ SECTION
1 PERS RES OFC DA ATTN CHF S&D
1 CHF PERS MGT DP RES & DEVEL DIV
ADJ GEN OFC ATTN AGTP A

1 SYSTEMS DEVEL BR ADJ GEN OFC DA
ATTN AGTP M
1 USA COMBAT SURVEILLANCE AGY
OFC CHF SIG OFF
1 ACS RESERVE COMPONENTS DA
10 CDR ARMED SERV TECH INFO AGY
ARLINGTON VA ATTN TIPCR
1 CO USA MED RES LAB FT KNOX
1 CHF RES & DEVEL DA ATTN TECH LIAISON OFC
1 RES & TNG DIV ORDHC OFC CHF ORD DA
2 PRES USA ARMOR BD FT KNOX
1 PRES US ARMY MAT COMD BD
ABERDEEN PROV GND
1 DIRECTOR US ARMY COMMEL COMBAT
DEVEL AGY FT MONMOUTH
1 PRES USA TRANS BD FT EUSTIS
ATTN TECH DIR
1 CO US ARMY MIL POLICE
COMBAT DEVEL AGY FT GORDON
1 1ST INF DIV 1ST MED TK BN
69TH ARMOR FT RILEY
1 3D INF DIV 1ST MED TK BN
69TH ARMOR APO 36 NY
1 CO 3D MED TK BN 32D ARMOR
USA ARMOR CTR FT KNOX
1 GEORGIA FLORIDA NATL GRD
48TH ARMORED DIV JACKSONVILLE
1 NY NATL GRD HQ 27TH ARMORED DIV BUFFALO
1 TEXAS NATL GRD 49TH ARMORED DIV DALLAS
9 CO USA ARMOR CTR FT KNOX
ATTN G3 AISKT T
1 CG 4TH INF DIV FT LEWIS ATTN G3
1 CG FT CARSON ATTN G3
1 CG HQ USA HAWAII APO 957 SAN FRAN
ATTN G3
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PT WASHINGTON LI ATTN LIBN
1 CHF PSYCHOLOGIST HUMAN ENGIN DEPT
US NAV TNG DEV CTR PT WASHINGTON LI
1 CDR FLEET TNG GP
US NAV BASE CHARLESTON
2 HD MASS COMM BR COMM PSYCHOL DIV US
NAV TNG DEVICE CTR PT WASHINGTON
1 CHF NAV RES DN ATTN HD PERS & TNG BR
CODE 458
1CHF NAV RES DN ATTN DIR PSYCHOL
SCI DIV CODE 450
1 OFF IN CHG US NAV PERS RES ACTIVITY
US NAV WEAPONS PLANT
25 CO NAV RES BR OFC NAVY 100 NY
1 CO MED FLD RES LAB CAMP LEJEUNE
1 CDR PAC MISSILE RANGE US NAV MISSILE CTR
PT MUGU CALIF ATTN TECH LIB CODE 310
1 COMDT MARINE CORPS CODE AO 1B
1 COMDT MARINE CORPS
HQ US MARINE CORPS ATTN AO 4E
1 DIR MARINE CORPS INST ATTN EVAL UNIT
1 CHF NAV AIR TECH TNG NAV AIR STA MEMPHIS
3 DIR TNG DCS P HQ US AIR FORCE ATTN PTR P
1 CHF LIFE SCI GRP DIRCTE RES
DCS RES & TECHNOL HQ USAF
1 FED AVIAT AGY CHF INFO RETRIEVAL
SECT MS 112 LIB BR
1 HQ AFSC SCGS 3 ANDREWS AFB
2 HQ WRIGHT AIR DEVEL DIV
WRIGHT PATTERSON AFB ATTN WWRDST
1 AMD MRPTO WRIGHT PATTERSON AFB
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PERS SUBSYS BR BSOSP NORTON AFB
1 AEROSPACE MED DIV AMRH BROOKS AFB
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ATTN AEROMED LIB
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SEATTLE
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1 ACS INTEL FOREIGN LIAISON OFF
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1 NATL INST ALCOHOL RES OSLO NORWAY
1 DEPT PSYCHOL YORK U TORONTO ONT CAN
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   ENGIN & ANAL SERV PROJ
1 AMERICAN PSYCHOL ASSN
1 HD DEPT PSYCHOL NORTHERN ILLINOIS U
1 BELL TEL LABS INC TECH INF LIB
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1 HD TECH PROCESSING GEN LIB DUKE U
1 DOCUMENTS DEPT GEN LIB U CALIF
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1 SERIALS DEPT LIB U ILL
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1 ACQUISITIONS DEPT LIBS U NEBRASKA
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1 PERIODICALS CHECKING FILES PURDUE U LIBS
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1 SOUTHERN ILL U ATTN LIBN SERIALS DEPT